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(54) AXIAL FAN ASSEMBLY WITH STATOR VANE HAVING BOTH CHORDWISE AND SPANWISE CAMBER

AXIALLÜFTER MIT LEITSCHAUFELN MIT SEHNENWEISER WIE AUCH SPANNWEISER KRÜMMUNG

VENTILATEUR AXIAL AVEC AUBES DE STATOR AYANT UNE CAMBRURE DANS LE SENS DE LA CORDE ET DANS LE SENS DE L’ENVERGURE

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US-A- 5 342 167	**US-A- 6 139 265**

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Description

[0001] The invention concerns stator vanes which support a cooling fan motor, such as in an automotive application. The stator vanes have cambered airfoil cross sections and also have camber along their lengths, or spans.

[0002] In particular, the invention refers to a fan assembly as defined in the preamble of Claim 1. Such a fan assembly is known e.g. from US 6 139 265.

BACKGROUND OF THE INVENTION

[0003] Fig. 1 is a simplified cross-sectional schematic drawing of a cooling fan. Ring 3, also shown in Fig. 2, supports an array of radial stator vanes 6, shown in both Figures. Ring 3 is anchored to an external support (not shown). Stator vanes 6 in Fig. 1 support an inner ring 9, which is also shown in Fig. 2. It should be understood that the structure identified as ring 9 does not have to take the form of a ring or a complete cylindrical 360°body of revolution. Inner ring 9 in Fig. 1 supports a motor, diagrammatically indicated as motor 12, which may be an electric or hydraulic motor. Motor 12 drives fan blades 15, which are supported by bearings 18.

[0004] Ideally, inner ring 9 acts as a perfectly rigid support for the motor 12. However, in practice, this ideal is not attained, and the motor 12 and the inner ring 9 can move in an axial or tangential fashion, which is not desired.

[0005] Further, a given fan system will possess certain natural or resonant frequencies. If an excitation occurs at these frequencies, as when the fan is attached to an automotive engine and the engine vibrates at such frequencies, the fan system will sympathetically vibrate at these frequencies. In general, such sympathetic vibration is not desired. A sympathetic vibration of the fan system can be the source of objectionable noise or vibration that can be noticed within the passenger compartment.

[0006] Other fan systems of the prior art are disclosed in US6139265A, US5342167A, US2154313A, FR1499693A, EP1312754A and DE4228879A1.

SUMMARY OF THE INVENTION

[0007] An object of the invention is to provide an improved fan mounting system.

[0008] The invention is defined in Claim 1. Further characteristics are contained in the dependent claims.

[0009] In one form a motor support is carried by an array of spiral arms, each arm being concave on its radially outer side.

[0010] A motor vehicle may comprises a cooling fan rotatably driven by a motor, the cooling fan comprising a support which carries a motor which drives fan blades and stators coupled to the support, the stators being chordwise concave on a first side and are spanwise concave on a second side.

[0011] Thus an apparatus may comprise a base effective to support a fan motor, a plurality of supports extending from the base, the plurality of supports each redirecting exhaust of the fan and increasing natural frequency of the base-support combination in at least one mode of vibration, compared to a second base-support combination comprising a plurality of radial supports.

[0012] Each of the plurality of stator vanes has at least two sides, both sides being preferably generally arcuate.

[0013] While the form of apparatus herein described constitutes a preferred embodiment of this invention, it is to be understood that the invention is not limited to this precise form of apparatus, and that changes may be made therein without departing from the scope of the invention as defined in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 is a simplified cross-sectional schematic of a prior-art cooling fan;

Fig. 2 is a perspective view of rings 3 and 6 of Fig. 1;

Fig. 3 is a simplified perspective view of one form of the invention;

Fig. 4 illustrates conventional terminology used to describe airfoils in the prior art;

Fig. 5 illustrates an axial force applied during finite element modeling;

Figs. 6 - 7 illustrate exaggerated views of the deformation that occurs at the first resonant mode of the structures;

Fig. 8 illustrates simulation results indicating the response of radial stators to the applied moment of Fig. 10;

Fig. 9 illustrates simulation results indicating the response of dual-cambered stators of the type shown in Fig. 3, to the applied moment of Fig. 10;

Fig. 10 illustrates a moment applied about the axis of rotation of the fan, applied during finite element modeling;

Fig. 11 illustrates simulation results indicating the response of radial stators to the applied gymbaling force of Fig. 13;

Fig. 12 illustrates simulation results indicating the response of dual-cambered stators of the type shown in Fig. 3, to the applied gymbaling force of Fig. 13;

Fig. 13 illustrates a moment applied perpendicular to the axis of rotation of the fan, applied during finite element modeling;

Figs. 14 and 15 are summaries of results of finite element analyses;

Fig. 16 illustrates one form of the invention;

Figs. 17 and 18 illustrate a specific embodiment;

Fig. 19 illustrates reference directions in a cylindrical coordinate system;

Figs. 20 - 23 illustrate various references or definitions for spanwise or chordwise camber direction;

and

Figs. 24A - 29B show reduction in out-of-plane and in-plane deformation and Von Mises stress with the dual-cambered stators.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Fig. 3 is a simplified rendition of one form of the invention, showing a motor mount ring 30, which is analogous in function to inner mounting ring 9 in Figs. 1 and 2. In Fig. 3, stator vanes 33 are attached to the inner ring 9, and also to an outer ring, or individual support members shown as element 32, which is analogous in function to outer ring 3 in Figs. 1 and 2.

[0016] In Fig. 3, the stator vanes 33 are constructed with two types of camber. Camber generally is illustrated in Fig. 4, which illustrates a cross-sectional view of an airfoil. The mean camber line is the line which is midway between the lower and upper surfaces, with the distance being measured perpendicular to the mean camber line. The forwardmost point of the airfoil is the leading edge, and the rearmost point is the trailing edge, as indicated.

[0017] The straight line connecting the leading edge and the trailing edge is the chord line. The camber is the maximum distance between the mean camber line and the chord line, as indicated. This type of camber will be called chordwise camber because it is measured with respect to, or along, the chord of the airfoil.

[0018] In Fig. 3, the vanes 33 are shown by wireframe representations of the mean camber lines of the vanes 33: the vanes 33 are illustrated as having no thickness, and the cross-sections of the vanes are not shown for ease of illustration. Nevertheless, it is understood that the vanes 33 are three-dimensional airfoils. Therefore, one feature of the stator vanes 33 is that they possess chordwise camber.

[0019] A second feature is that the stator vanes 33 have spanwise camber. That is, a span line 58 is defined as the straight line running from the root 52 to the tip 55 of the stator vane 33. Spanwise camber is a distance, measured perpendicular to the span line 58, from the span line 58 to the camber line CL, shown in wire frame. Alternately, spanwise camber can be termed a distance from the span line 58 to the surface (not shown) of the stator vane 33.

[0020] On the other hand, the concavity of the spanwise camber faces counter-clockwise. For example, the spanwise concavity of the same blade at the 3 o'clock position is concave upward. That direction is counter-clockwise from the vane 33.

[0021] From another perspective, the vanes 33 in Fig. 3 are chordwise concave because they are concave along a chord. Also, the vanes 33 are spanwise concave, because they are concave along the span line 58.

[0022] From another perspective, in considering the vanes 33 as airfoils, the pressure side (that is, the bottom side in Fig. 4) has a surface running from the leading edge to the trailing edge. That surface in Fig. 3 is concave, and the concavity is bounded by the leading and trailing edges.

[0023] From another perspective, the vanes 33 in Fig. 3 collectively form an array of spiral arms, extending between the inner ring 30 and outer ring 32. The arms are concave on their radially outer, RO, sides, as indicated in the Figure.

[0024] For ease of understanding, Applicants are including several illustrations in Figs. 20 - 23. Fig. 20 illustrates a chordwise camber as viewed from a rear direction (i.e., as if airflow was coming directly toward the reader out of the page). When viewed from the downstream or pressure side, the chordwise positive camber reference direction is the same direction as circumferential travel along the concave path starting at the trailing edge and ending at the leading edge. Notice that by this definition, the positive camber direction is clockwise. Alternatively, the direction of chordwise camber can be viewed from the downstream or pressure side, the positive camber reference direction is the same direction as a perpendicular vector V (Fig. 21) starting from the chord line, going towards the mean line. In the illustrations being described, this definition leads to a positive camber direction that is counter-clockwise as illustrated in Fig. 21.

[0025] Still another way to describe the chordwise camber direction is by reference to the direction of fan rotation, rather than as a counter-clockwise or clockwise reference. Therefore, alternatively, the camber direction can be referred to as a chordwise positive camber direction that is counter to the direction of fan rotation if the chordwise camber reference direction is as viewed in Fig. 20, or chordwise positive camber direction is the same as the direction of the rotation of the fan if the definition or reference of the chordwise is that which is referred to in Fig. 21. For ease of illustration and simplicity, the definition and reference for the chordwise camber as referred to in Fig. 21 will be used to describe various features of the invention.

[0026] For ease of illustration, the term sweep or spanwise camber, when viewed from a downstream or pressure side of the fan, the spanwise positive camber reference direction is the same direction as the radial travel along a concave path starting at an inner section (small radius) section and ending at a tip section (a large radius) connecting the same features on the inner and outer airfoil cross sections referred to below (that is, both leading edge, or both trailing edge, or both mid-chord locations). Note that if this is the same direction as a perpendicular vector starting from a line connecting the same features on the inner and outer airflow cross-section (that is, both leading edge, or both trailing edge, or both mid-chord locations), going towards a concave path starting at the inner section (the smallest radius section) and ending at the tip section (the largest radius section). If this is the reference, then note that the positive camber direction is clockwise as illustrated in Fig. 23.

[0027] As with the positive chordwise camber, instead of describing the spanwise direction reference as clockwise or counter-clockwise, the spanwise camber direction reference can be linked to the direction of fan rotation. This leads to the alternative definitions which are that the positive spanwise camber direction is the same as the direction of the fan rotation if the reference is the reference or definition referred to in Fig. 22 above as viewed from the downstream side of the fan. Alternatively, if the reference or definition is that which is shown in Fig. 23, then a positive spanwise camber direction is counter to the direction of fan rotation.

[0028] For ease of illustration, the reference of definition referred to in Fig. 23 will be used in the following part of the description.

[0029] The particular structure of the vanes 33 in Fig. 3 provides several desirable features. The features were demonstrated by finite element analyses undertaken of (1) radial, chordwise cambered vanes, which lack spanwise camber, such as vane 6 in Fig. 2 (camber is not shown), and (2) dual-cambered vanes of the type shown in Fig. 3.

[0030] In one analysis, a cyclic axial force was applied to inner ring 9, while outer ring 3 is held stationary. Fig. 5 illustrates the force 50. Figs. 6 and 7 are exaggerated views of the deformation that occurs at the first resonant mode of the vanes 33. The contour magnitudes are not "real," but give the relative deformation of different parts of the structure with respect to each other. Note also that Figs. 24 - 26 show reduction in out-of-plane and in-plane deformation and Von Mises stress with the dual cambered stators. The software used to perform the analysis produced a scale 55, which is displayed on a computer monitor as a multicolored spectrum. Because the Figures are monochrome drawings, the colored spectrum will not be used, but arrows will connect colored cells in the scale 55 to the corresponding regions of the vanes. For example, arrow A1 indicates a relative deflection in the range of 21.5 to 24.1 units for region 58.

[0031] It should be noted that the force 50 in Fig. 5 is cyclic, and thus the deflection will be cyclic, that is, in-out-in-out. Fig. 6, and similar Figures, illustrates the deflection occurring at the time of maximum deflection.

[0032] Arrow A2 in Fig. 7, compared with arrow A1 in Fig. 6, indicate that the deflection of the corresponding regions is smaller for the dual-cambered stators of Fig. 3.

[0033] In the simulations of Figs. 8 and 9, a moment was applied to the inner ring 9, with outer ring 3 held stationary. Fig. 10 illustrates the moment 60 applied to the inner ring 9. Figs. 8 and 9 are exaggerated views of the deformation that occurs at higher resonant modes of the structures (mode 2 for the radial stators - Fig 8, and mode 4 for the dual-cambered stators - Fig. 9). Note also that Figs. 27A-27B, 28A-28B and 29B-29B show reduction in out-of-plane and in-plane deformation and Von Mises stress with the dual-cambered stators 33. A comparison of arrow A5 in Fig. 9 with arrow A6 in Fig. 8 indicates, again, that deflection is less for the dual-cambered stators of Fig. 3. Figs. 11 and 12 are exaggerated views of the deformation that occurs at higher resonant modes of the structures (mode 3 for the radial stators - Fig. 11, and mode 2 for the dual-cambered stators - Fig. 12).

[0034] Fig. 13 illustrates the gymbaling force 70. It applies a moment about an axis which is perpendicular to the axis AX of the fan in Fig. 5. The drop in natural frequencies associated with the "gymbaling" (out of plane bending) modes with dual-cambered stators implies that these stators are relatively less stiff for these modes. Although there is a loss of stiffness, the out of plane bending modes typically occur at higher frequencies compared to the axial and torsional modes of radial stators, so these frequencies are not that much of a concern from a vehicle application point of view.

[0035] Fig. 11 illustrates the simulation for the case of radial stators. Fig. 12 illustrates the case of dual-cambered stators, of the type shown in Fig. 3. A comparison of arrow A7 in Fig. 11 with arrow A9 in Fig. 12 indicates, again, that deflection is less for the dual-cambered stators of Fig. 3.

[0036] Fig. 14 is a summary of simulation results. Line L1 refers to the situations of Figs. 6 and 7. Line L2 in Fig. 14 refers to the situations of Figs. 8 and 9.

[0037] Column C1 refers to the radial stators, of Figs. 6, 8, and 10. Column C2 refers to the dual-cambered stators of the type shown in Fig. 3, in the simulations of Figs. 7, 9, and 12. Column C3 refers to the change in natural frequency found, between the radial stators and the dual-cambered stators. Column C4 refers to the change in global stiffness in the two cases.

[0038] In Fig. 14, the term "in-phase" refers to the fact that, in some deflections, all blades deform into approximately the same shape, as in Fig. 6 for example. "Out-of-phase" refers to the fact that all blades do not deform into the same shapes. For example, blades 80 and 83 in Fig. 11 deform into different shapes.

[0039] Simulations were also done for static loading. Fig. 15 is a summary of results. Line L10 refers to axial loading of the type shown in Fig. 5. Line L11 refers to an applied moment, of the type shown in Fig. 10.

[0040] Block B1 refers to the axial movement of the ring 9. However, this ring 9 does not form the "roots of the stators." Typically, the "roots" of the stator are the portions that deflect less, which are the tips of the stators 33 at the outer ring (3). "Radial" refers to radial stators. "Swept" refers to the dual-camber stators of Fig. 3. Block B2 refers to the circumferential movement of the ring 6, or roots of the stators, in the direction of the arrow shown in Fig. 10. Block B3 refers to the changes in Von Mises Stresses.

[0041] Fig. 16 illustrates one form of the invention. A heat exchanger 95, such as a cooling radiator, is present within a motor vehicle 100. A fan 110 is present, having dual-cambered stators 115, of the type discussed herein.

[0042] Fig. 17 illustrates a specific embodiment of the stators, in cross-section. The tangent 145 to the camber line 135 at the leading edge LE is parallel to the mean incoming airstream 140, at one operating point of the system. The direction of the mean incoming airstream 140 will change, as the operating point (that is, engine speed) changes. The operating point selected at which parallelism is secured may be (1) the operating point which occurs most often in time, (2) the operating point at which the cooling system requires the maximum volume of cooling airflow, or (3) another desired point.

[0043] The tangent 150 to the camber line 135 at the trailing edge TE is parallel to the axis of rotation AX.

[0044] Fig. 18 is a view, viewed from the direction of arrow E in Fig. 16. The vanes, represented by camber lines 135, accept the incoming airstreams 140, which represent the exhaust of the fan 125 in Fig. 16, and which have a component of motion in the tangential direction.

[0045] Each adjacent pair of vanes cooperates to define an inlet channel, having a central axis CAX. The vanes are configured so that the central axis CAX of the inlet channel is parallel to the incoming airstreams 140. The vanes redirect the incoming airstreams to be parallel with the axis AX.

[0046] The term axis of concavity can be defined. In Fig. 4, such an axis would lie midway between the leading and trailing edges and extend perpendicularly into the paper. For example, if the bottom surface of the airfoil shown were parabolic in shape, concave downward, then the axis of concavity would be a line coincident with the focus of the parabolic surface.

[0047] Numerous substitutions and modifications can be undertaken without departing from the scope of the invention as defined in the following claims.

Claims

1. Axial fan assembly, comprising:

  a) a ring (30) which supports a fan motor (12) which drives fan blades (15), and
  b) stator vanes (33) which support the ring (30), and which re-direct exhaust of the fan blades (15), the stator vanes (33) having

    i) a chordwise camber and
    ii) a spanwise camber,

  wherein a positive chordwise camber direction is the direction of a perpendicular vector (V) starting from the chordline of the stator vane (33) and going toward the main line of said stator vane (33),
  characterised in that a tangential component of the positive chordwise camber direction parallel to the plane of fan rotation is aligned with the direction of fan rotation.

2. Axial fan assembly according to claim 1, wherein the chordwise camber is concave in a clockwise direction.

3. Axial fan assembly according to claim 1, wherein the spanwise camber is concave in a counter-clockwise direction.

4. Axial fan assembly according to claim 1, wherein the tangential component of the positive spanwise camber direction is opposed to the component of the positive chordwise camber direction parallel to the plane of fan rotation.

5. Axial fan assembly according to claim 1 wherein said fan is mounted in operative relationship to a radiator in a motor vehicle in which the fan is mounted, and used for cooling purposes.

6. Axial fan assembly according to claim 1 wherein said stator vanes are chordwise concave on a first side and spanwise concave on a second side.

7. Axial fan assembly according to any of preceding claims wherein the vanes (33) are non-radial including at root level.

8. Axial fan assembly according to claim 1, wherein each side of each of said plurality of stator vanes (33) has an axis of concavity and the two axes are non-parallel.

9. Axial fan assembly according to claim 8, wherein the two axes are perpendicular.

10. Axial fan assembly according to claim 1, wherein each of said plurality of stator vanes (33) comprises a concave surface on its radially outside surface.

11. Axial fan assembly as recited in claim 1 wherein each of said stator vanes (33) is swept in a predetermined direction that is the same as the direction of rotation of said fan.

12. Axial fan assembly as recited in claim 1 wherein each of said plurality of stator vanes (33) comprises a longitudinal cross-section and a width-wise cross-section; said longitudinal cross-section defining a longitudinal radius of curvature that is larger than a width-wise radius of curvature of said width-wise cross section, said longitudinal radius of curvature being in a different direction than said width-wise radius of curvature.

Patentansprüche

1. Axiallüfter, umfassend:

  a) einen Ring (30), der einen Lüftermotor (12) trägt, der Lüfterblätter (15) antreibt, und
  b) Leitschaufeln (33), die den Ring (30) tragen

und abströmende Luft von den Lüfterblättern (15) umleiten, wobei die Leitschaufeln (33) Folgendes aufweisen:

i) eine sehnenweise Krümmung und
ii) eine spannenweise Krümmung,

wobei eine positive sehnenweise Krümmungsrichtung die Richtung eines rechtwinkligen Vektors (V) ist, der an der Sehnenlinie der Leitschaufel (33) beginnt und sich zu der Hauptlinie der Leitschaufel (33) erstreckt,
dadurch gekennzeichnet, dass eine tangentiale Komponente der positiven sehnenweisen Krümmungsrichtung, die parallel zu der Ebene der Lüfterdrehung verläuft, in einer Linie mit der Richtung der Lüfterdrehung ausgerichtet ist.

2. Axiallüfter nach Anspruch 1, wobei die sehnenweise Krümmung in einer im Uhrzeigersinn verlaufenden Richtung konkav ist.

3. Axiallüfter nach Anspruch 1, wobei die spannenweise Krümmung in einer gegen den Uhrzeigersinn verlaufenden Richtung konkav ist.

4. Axiallüfter nach Anspruch 1, wobei die tangentiale Komponente der positiven spannenweisen Krümmungsrichtung entgegengesetzt zu der Komponente der positiven sehnenweisen Krümmungsrichtung, die parallel zu der Ebene der Lüfterdrehung verläuft, ist.

5. Axiallüfter nach Anspruch 1, wobei der Lüfter in einer betrieblichen Beziehung zu einem Kühler in einem Kraftfahrzeug, in dem der Lüfter montiert ist, befestigt ist und zu Kühlungszwecken verwendet wird.

6. Axiallüfter nach Anspruch 1, wobei die Leitschaufeln auf einer ersten Seite sehnenweise konkav und auf einer zweiten Seite spannenweise konkav sind.

7. Axiallüfter nach einem der vorhergehenden Ansprüche, wobei die Schaufeln (33) auf Fußebene nicht radial inkludierend sind.

8. Axiallüfter nach Anspruch 1, wobei jede Seite von jeder aus der Vielzahl von Leitschaufeln (33) eine Konkavitätsachse aufweist und die beiden Achsen nicht parallel verlaufen.

9. Axiallüfter nach Anspruch 8, wobei die beiden Achsen rechtwinklig zueinander verlaufen.

10. Axiallüfter nach Anspruch 1, wobei jede aus der Vielzahl von Leitschaufeln (33) auf ihrer radial äußeren Fläche eine konkave Fläche umfasst.

11. Axiallüfter nach Anspruch 1, wobei jede der Leitschaufeln (33) in einer vorgegebenen Richtung geschweift ist, die identisch mit der Drehungsrichtung des Lüfters ist.

12. Axiallüfter nach Anspruch 1, wobei jede aus der Vielzahl von Leitschaufeln (33) einen Längsquerschnitt und Breitenquerschnitt umfasst, wobei der Längsquerschnitt einen längs verlaufenden Krümmungsradius festlegt, der größer als ein in der Breite verlaufender Krümmungsradius des Breitenquerschnitts ist, wobei der längs verlaufende Krümmungsradius in einer anderen Richtung als der in der Breite verlaufende Krümmungsradius verläuft.

Revendications

1. Ensemble de ventilateur axial, comprenant:

a) un anneau (30) qui supporte un moteur de ventilateur (12) qui entraîne des pales de ventilateur (15); et
b) des aubes de stator (33) qui supportent l'anneau (30), et qui redirigent l'échappement des pales de ventilateur (15), les aubes de stator (33) présentant

i) une cambrure dans le sens de la corde, et
ii) une cambrure dans le sens de l'envergure,

dans lequel une direction de cambrure positive dans le sens de la corde est la direction d'un vecteur perpendiculaire (V) qui démarre à partir de la ligne de corde de l'aube de stator (33) et qui s'étend en direction de la ligne principale de ladite aube de stator (33),
caractérisé en ce qu'une composante tangentielle de la cambrure positive dans le sens de la corde parallèle au plan de rotation du ventilateur est alignée avec la direction de rotation du ventilateur.

2. Ensemble de ventilateur axial selon la revendication 1, dans lequel la cambrure dans le sens de la corde est concave dans un sens horaire.

3. Ensemble de ventilateur axial selon la revendication 1, dans lequel la cambrure dans le sens de l'envergure est concave dans un sens antihoraire.

4. Ensemble de ventilateur axial selon la revendication 1, dans lequel la composante tangentielle de la direction de cambrure positive dans le sens de l'envergure est opposée à la composante de la direction de cambrure positive dans le sens de la corde parallèle au plan de rotation du ventilateur.

5. Ensemble de ventilateur axial selon la revendication 1, dans lequel ledit ventilateur est monté dans une relation opérationnelle sur un radiateur dans un véhicule à moteur dans lequel le ventilateur est monté, et est utilisé à des fins de refroidissement.

6. Ensemble de ventilateur axial selon la revendication 1, dans lequel lesdites aubes de stator sont concaves dans le sens de la corde sur un premier côté et concaves dans le sens de l'envergure sur un second côté.

7. Ensemble de ventilateur axial selon l'une quelconque des revendications précédentes, dans lequel les aubes (33) sont non radiales y compris au niveau de la racine.

8. Ensemble de ventilateur axial selon la revendication 1, dans lequel chaque côté de chacune de ladite pluralité d'aubes de stator (33) présente un axe de concavité et les deux axes sont non parallèles.

9. Ensemble de ventilateur axial selon la revendication 8, dans lequel les deux axes sont perpendiculaires.

10. Ensemble de ventilateur axial selon la revendication 1, dans lequel chacune de ladite pluralité d'aubes de stator (33) présente une surface concave sur sa surface radialement extérieure.

11. Ensemble de ventilateur axial selon la revendication 1, dans lequel chacune desdites aubes de stator (33) est balayée dans une direction prédéterminée qui est la même que le sens de rotation dudit ventilateur.

12. Ensemble de ventilateur axial selon la revendication 1, dans lequel chacune de ladite pluralité d'aubes de stator (33) comprend une section transversale longitudinale et une section transversale dans le sens de la largeur; ladite section transversale longitudinale définissant un rayon de courbure longitudinal qui est plus grand qu'un rayon de courbure dans le sens de la largeur de ladite section transversale dans le sens de la largeur, ledit rayon de courbure longitudinal s'étendant dans une direction différente de celle dudit rayon de courbure dans le sens de la largeur.

FIG-1
(PRIOR ART)

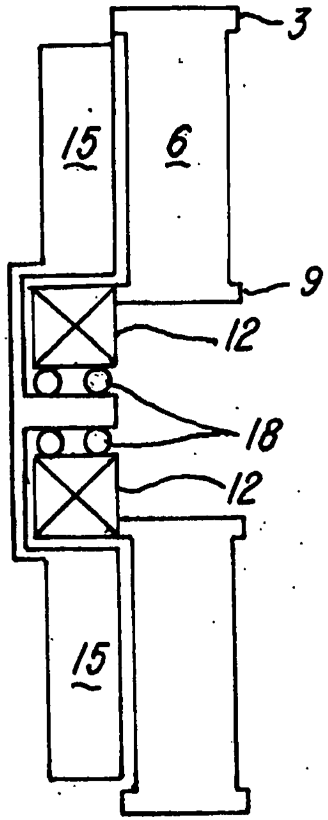


FIG-2
(PRIOR ART)

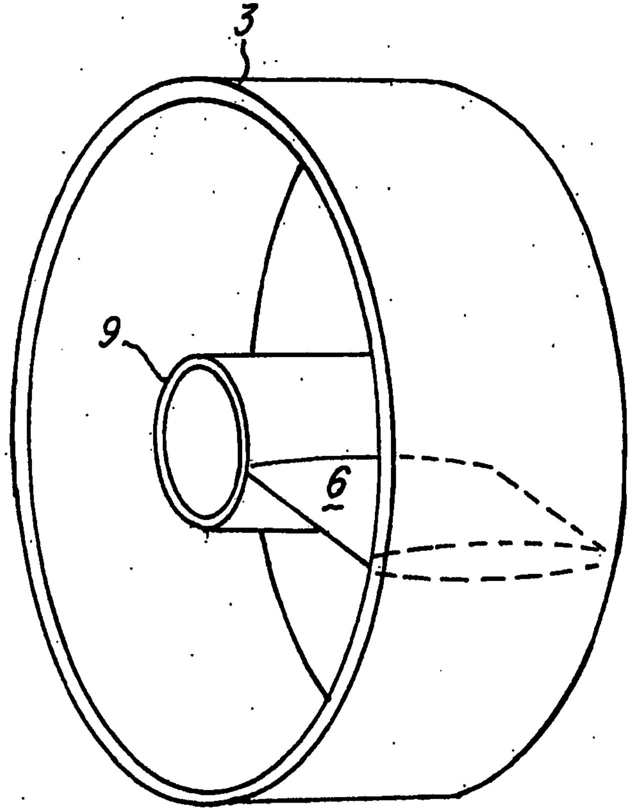


FIG-3

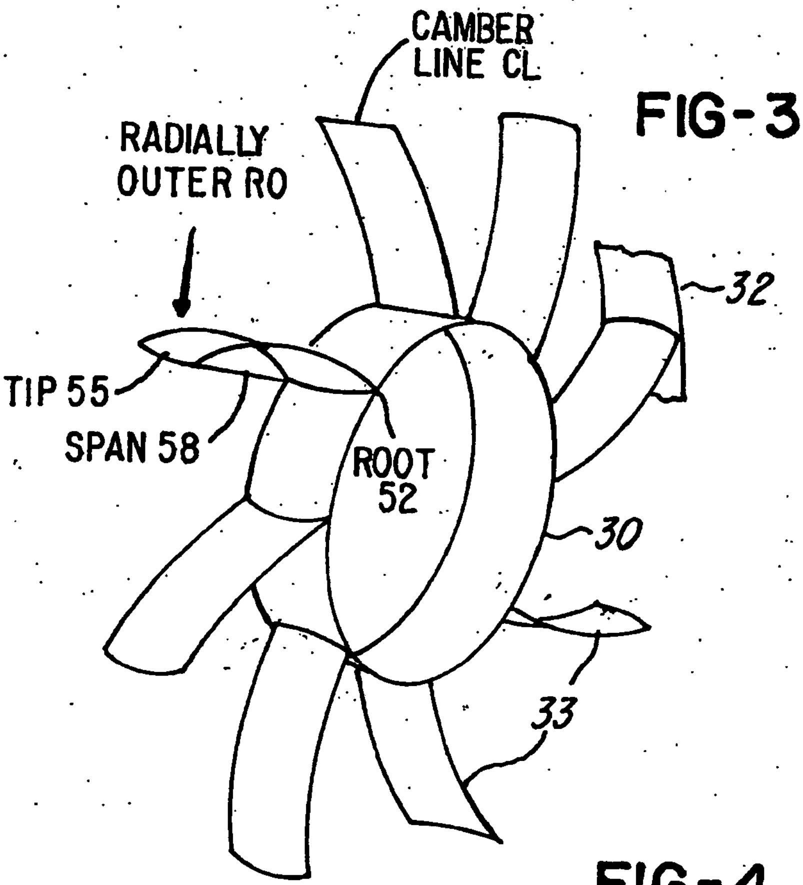


FIG-4

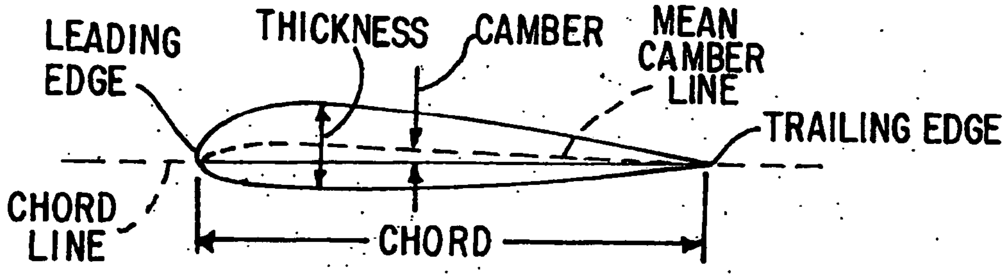


FIG-19

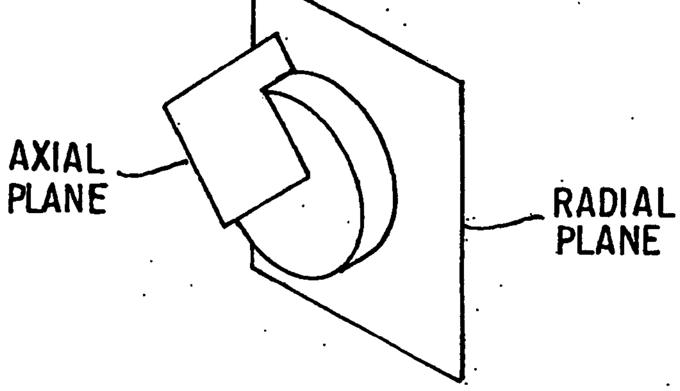


FIG-5

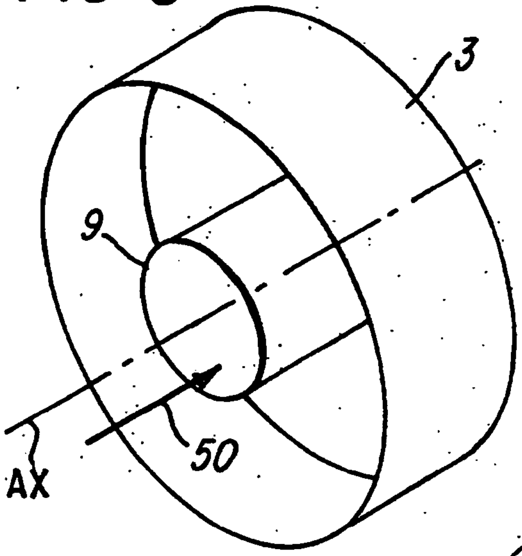


FIG-10

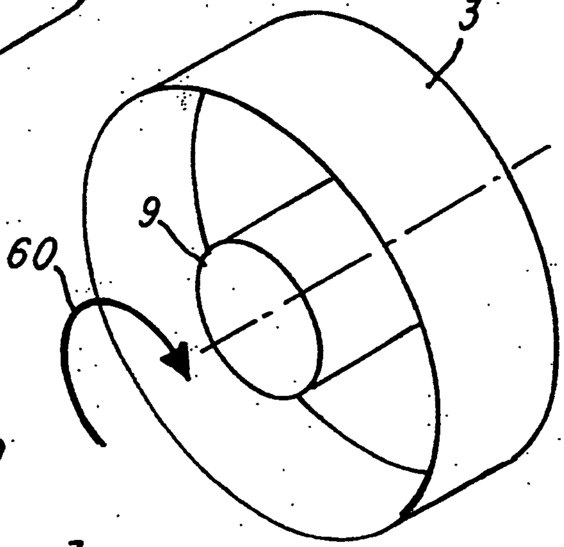


FIG-13

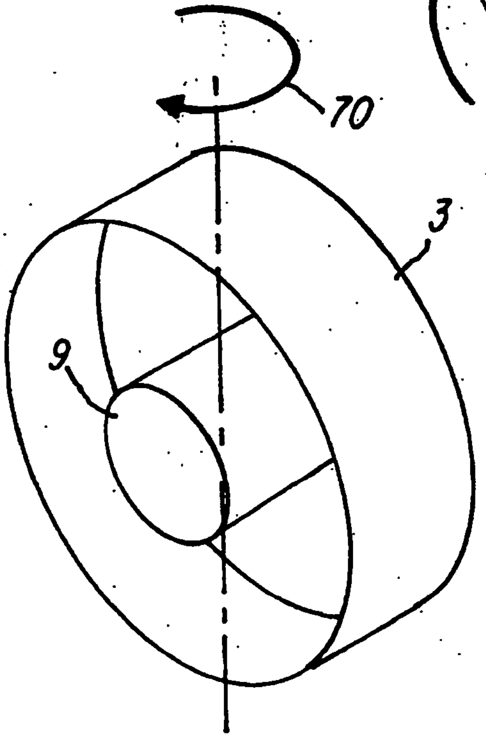


FIG-6

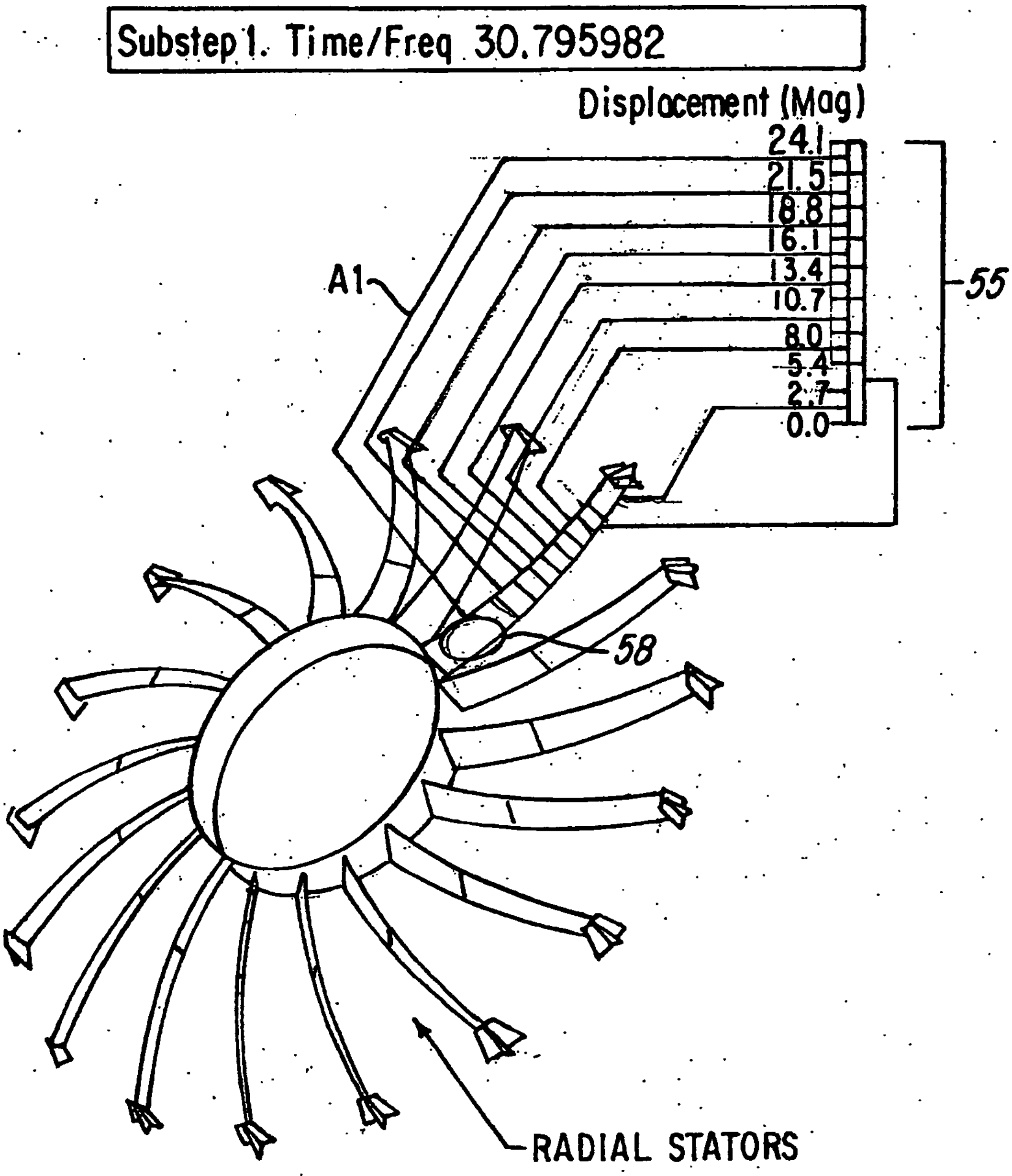

Substep 1. Time/Freq 30.795982
Displacement (Mag)
24.1
21.5
18.8
16.1
13.4
10.7
8.0
5.4
2.7
0.0
55
A1
58
RADIAL STATORS

FIG- 7

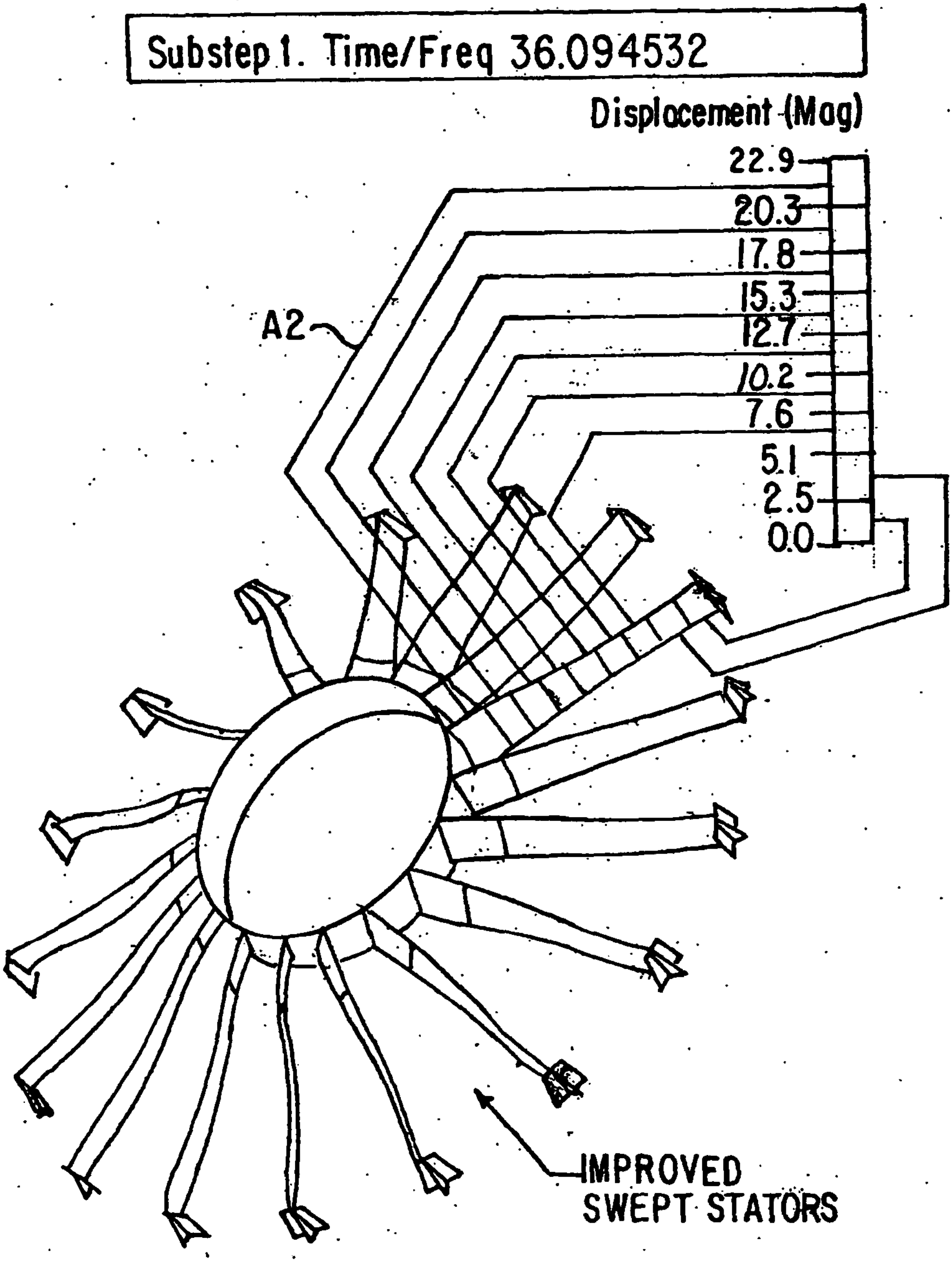

Substep 1. Time/Freq 36.094532
Displacement (Mag)
22.9
20.3
17.8
15.3
12.7
10.2
7.6
5.1
2.5
0.0
A2
IMPROVED
SWEPT STATORS

FIG-8

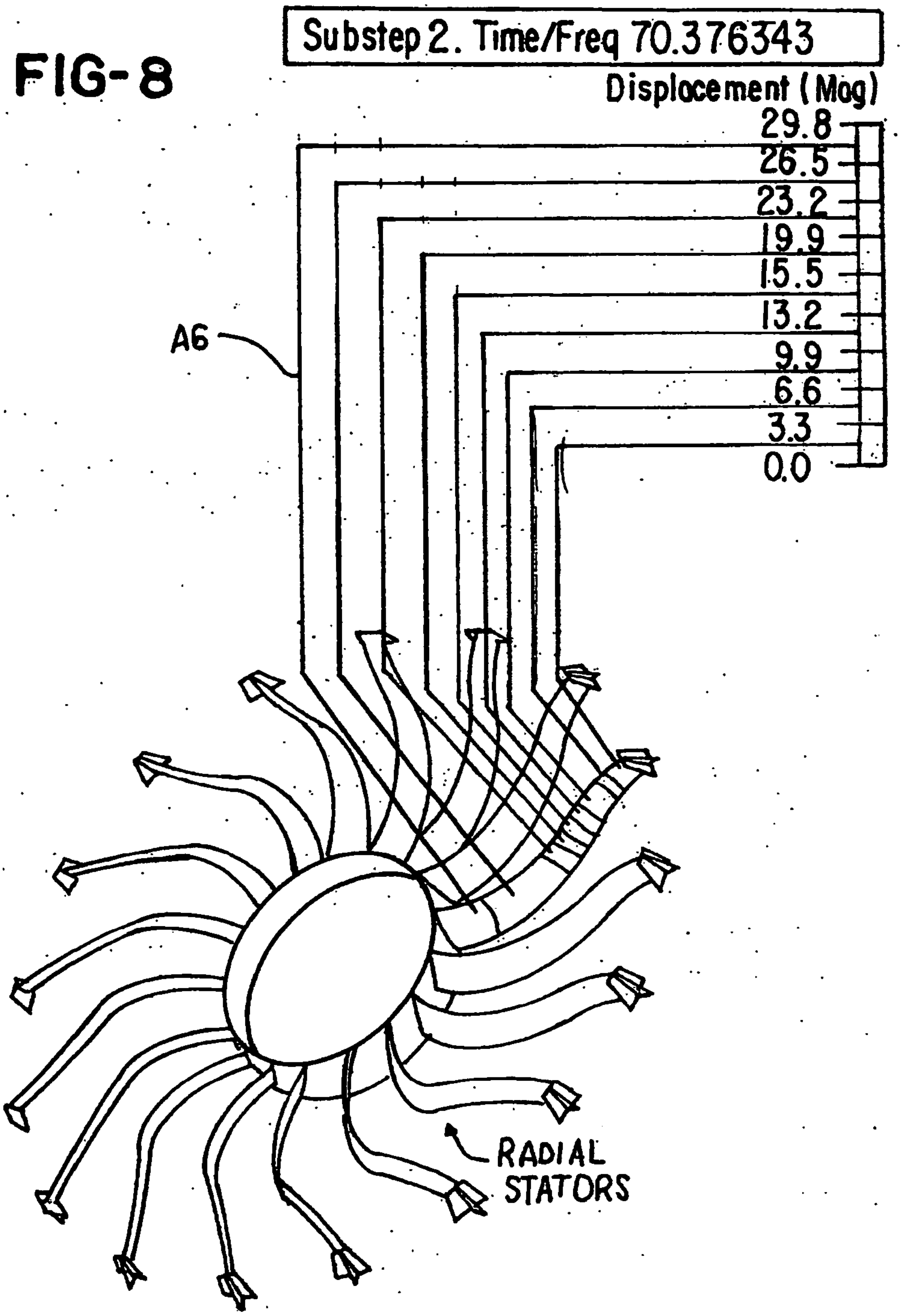

Substep 2. Time/Freq 70.376343
Displacement (Mag)
29.8
26.5
23.2
19.9
15.5
13.2
9.9
6.6
3.3
0.0
A6
RADIAL
STATORS

FIG-9

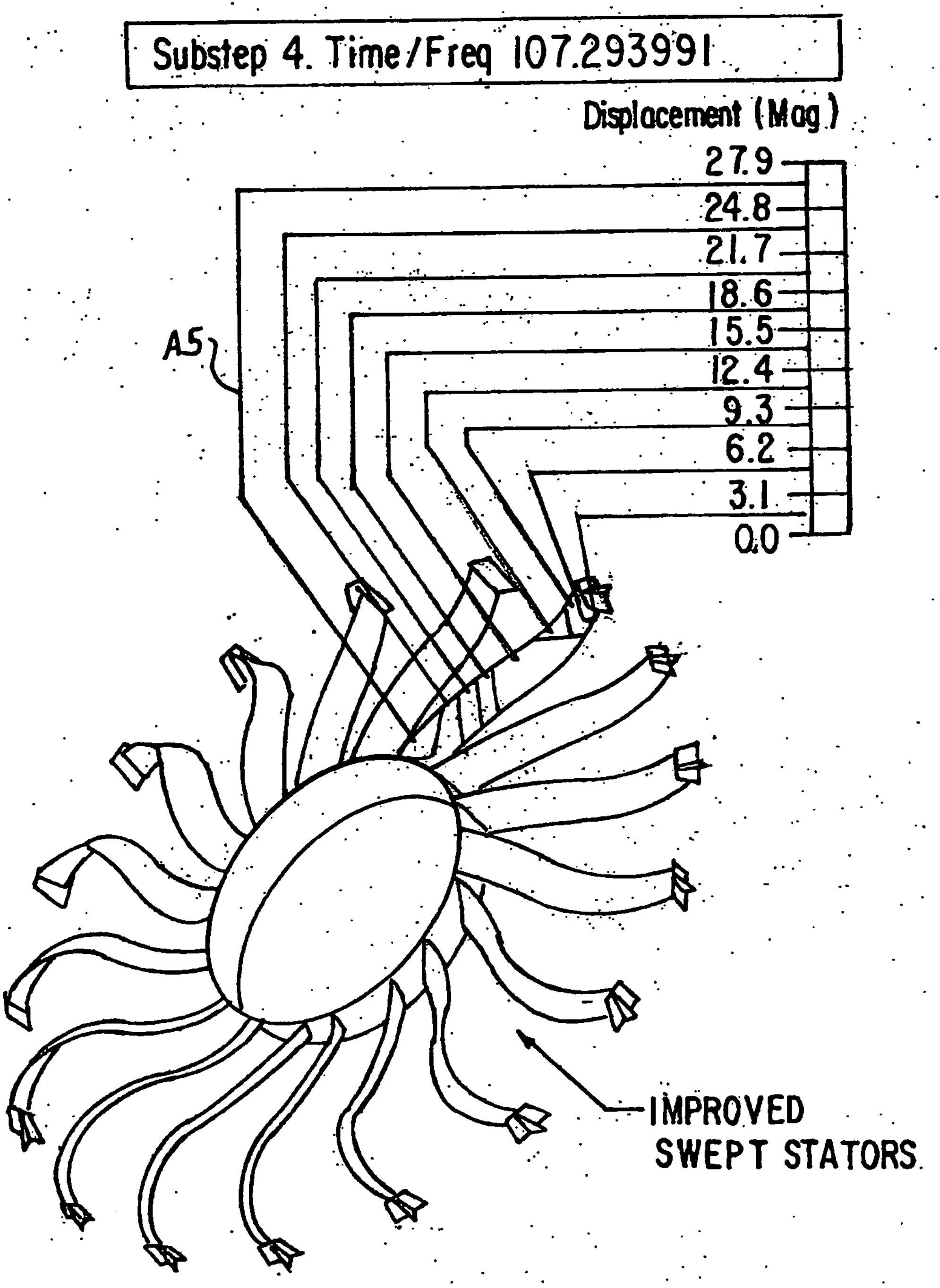

Substep 4. Time/Freq 107.293991
Displacement (Mag)
27.9
24.8
21.7
18.6
15.5
12.4
9.3
6.2
3.1
0.0
A5
IMPROVED
SWEPT STATORS.

FIG-11

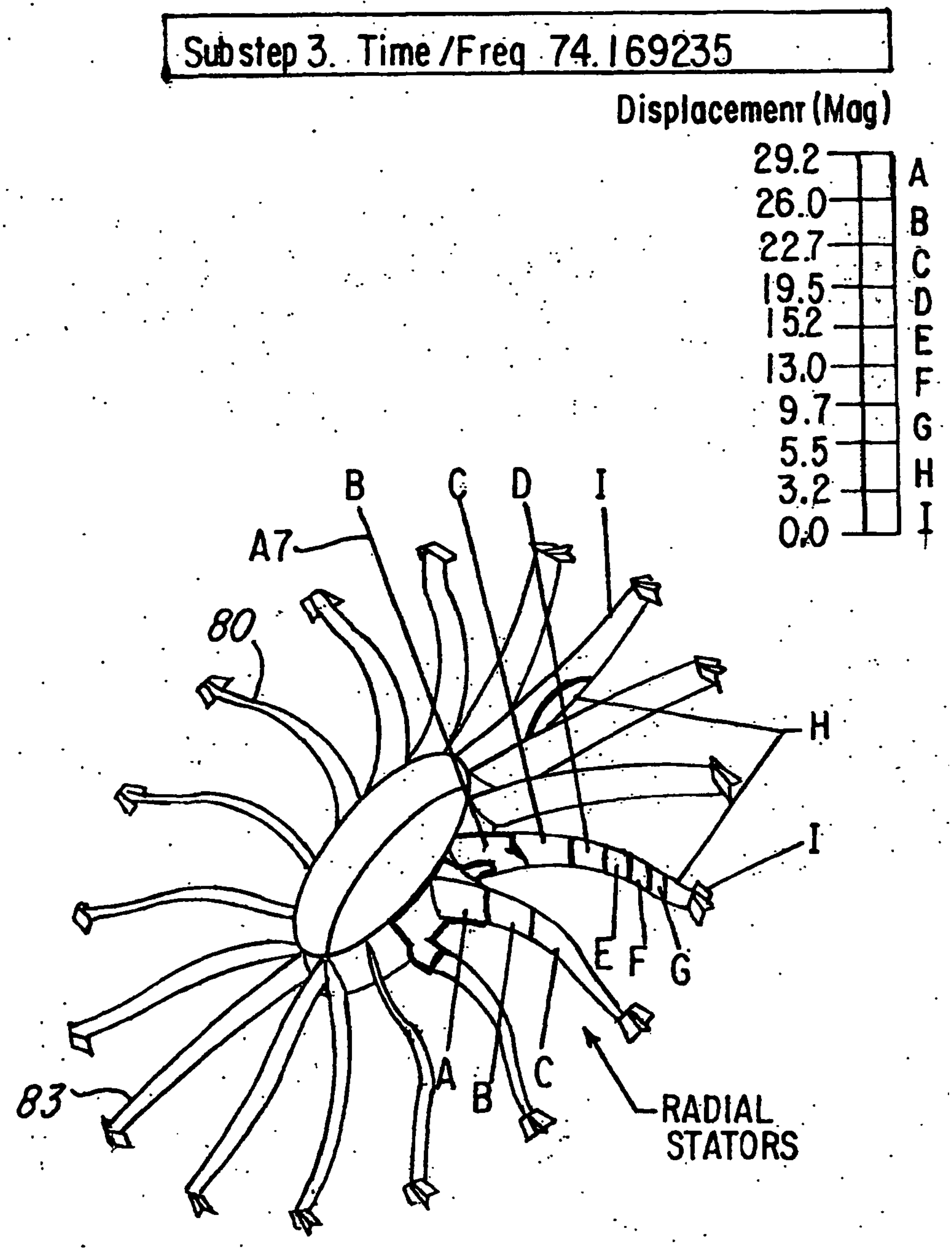

Substep 3. Time/Freq 74.169235
Displacement (Mag)
29.2
26.0
22.7
19.5
15.2
13.0
9.7
5.5
3.2
0.0
A
B
C
D
E
F
G
H
I
B
C
D
I
A7
80
H
I
E
F
G
A
B
C
83
RADIAL STATORS

FIG-12

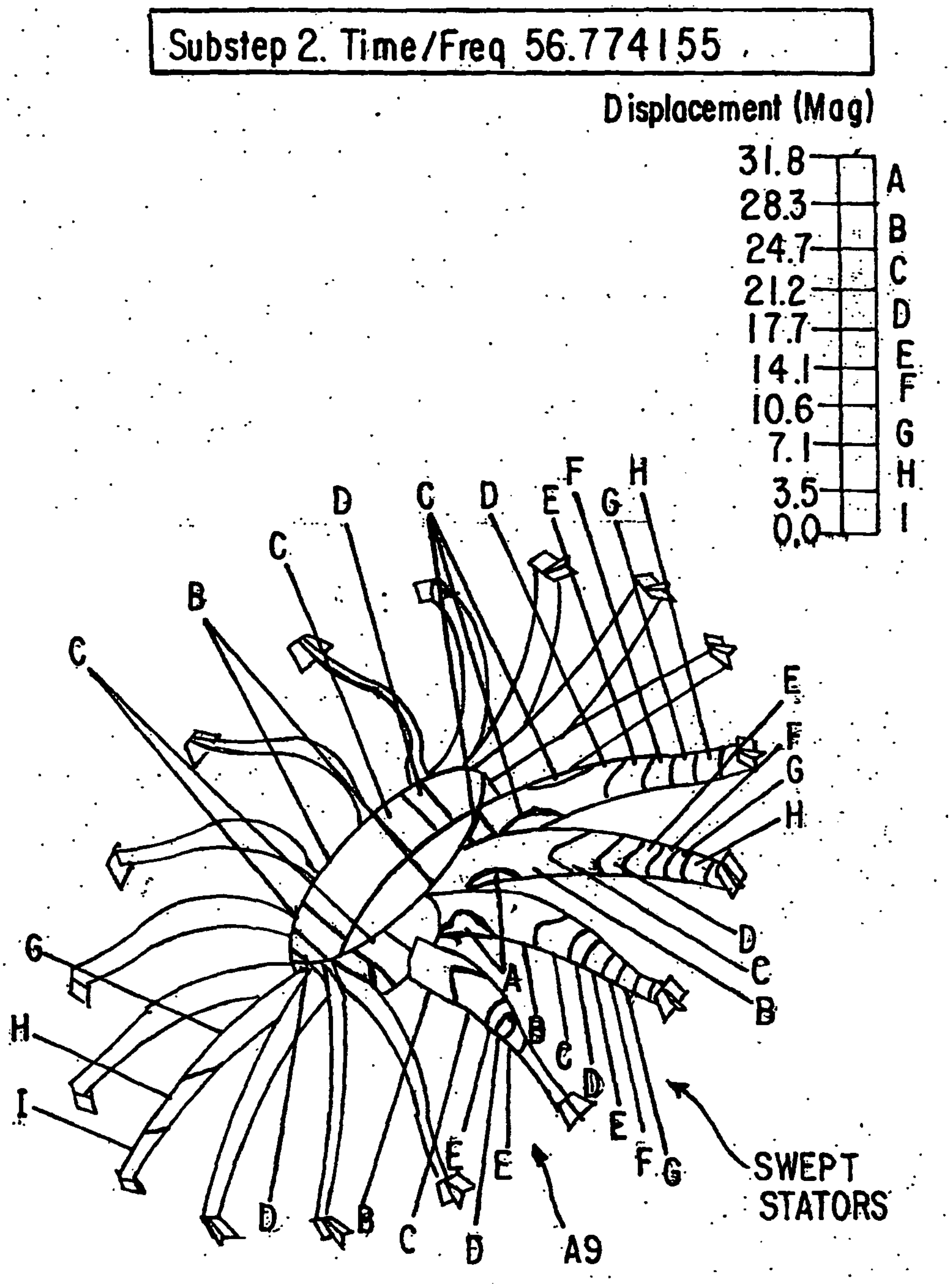

Substep 2. Time/Freq 56.774155
Displacement (Mag)
31.8 A
28.3 B
24.7 C
21.2 D
17.7 E
14.1 F
10.6 G
7.1 H
3.5 I
0.0
A
B
C
D
E
F
G
H
I
SWEPT STATORS
A9

FIG. 14

C1 C2 C3 C4

	Mode Shape	Frequency (Hz)		% Change in Frequency	% Change in Global Stiffness
		Baseline (Radial)	Swept		
L1	In-phase bending + twisting	30.8	36.1	+17%	+37%
L2	Twisting	70.4	107.3	+52%	+230%
	Out-of-phase bending (1)	74.2	66.8	-10%	-19%

FIG. 15

B1 B2 B3

	Load Case	Axial Deflection (mm)			In-Plane Deflection (mm)			Von Mises Stress (MPa)		
		Radial	Swept	%Change	Radial	Swept	% Change	Radial	Swept	% Change
L10	Force = -100N	-1.022	-1.014	-1%	0.657	0.320	-51%	15.2	12.9	-15%
L11	Moment = 6000N*mm	-0.560	-0.058	-90%	0.903	0.143	-85%	10.2	6.4	-37%

FIG-16

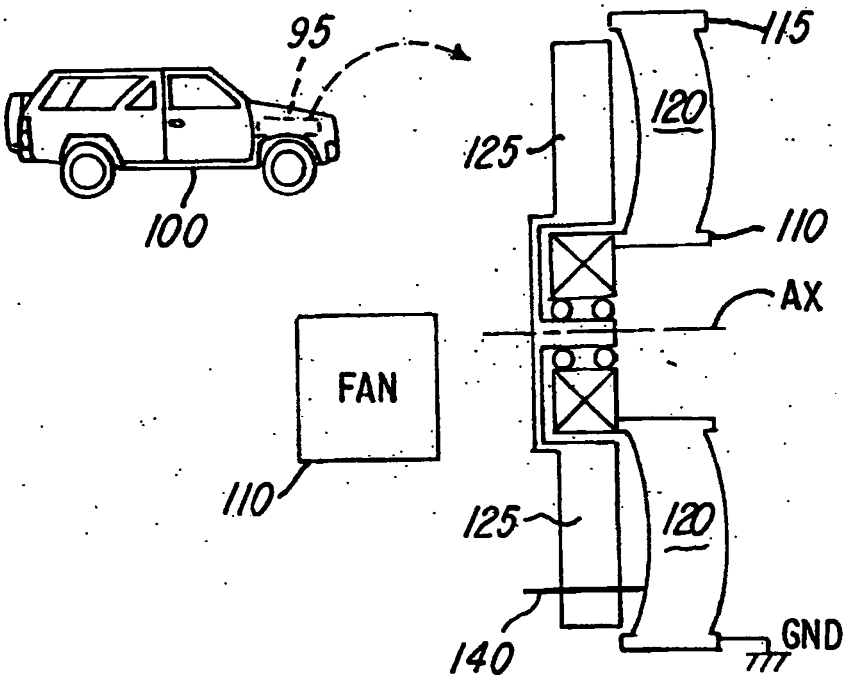


FIG-17

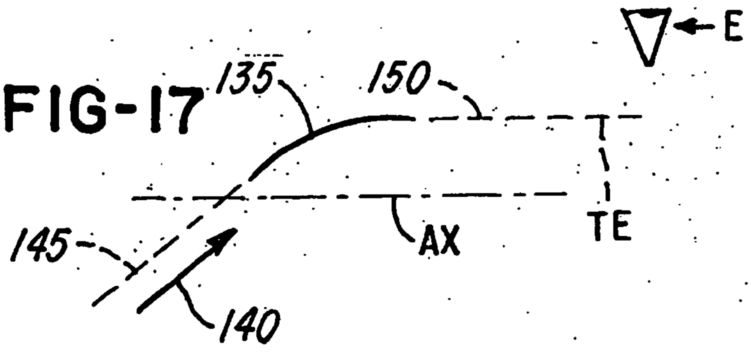


FIG-18

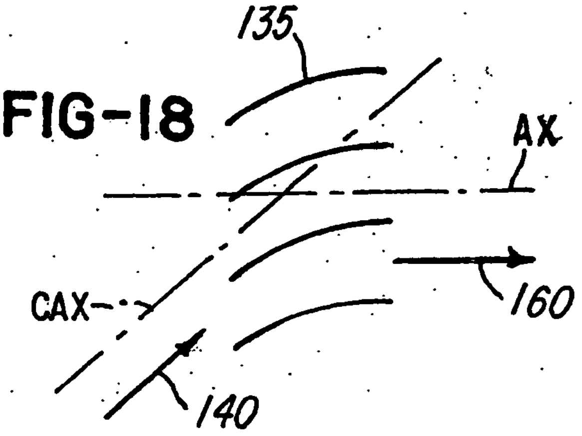


FIG-20

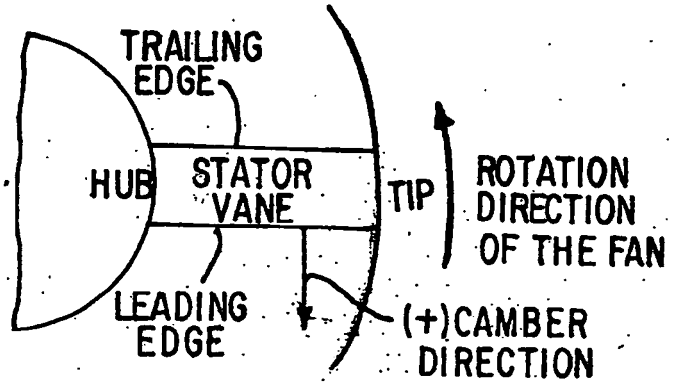

TRAILING EDGE
HUB
STATOR VANE
TIP
ROTATION DIRECTION OF THE FAN
LEADING EDGE
(+)CAMBER DIRECTION

FIG-21

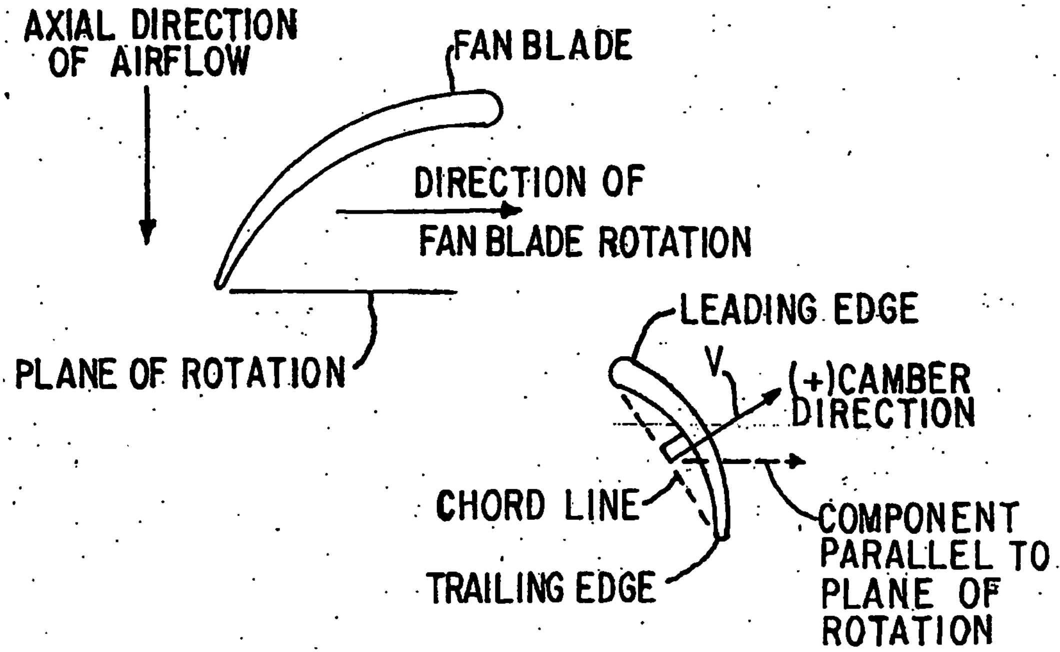

AXIAL DIRECTION OF AIRFLOW
FAN BLADE
DIRECTION OF FAN BLADE ROTATION
PLANE OF ROTATION
LEADING EDGE
V
(+)CAMBER DIRECTION
CHORD LINE
COMPONENT PARALLEL TO PLANE OF ROTATION
TRAILING EDGE

FIG-22

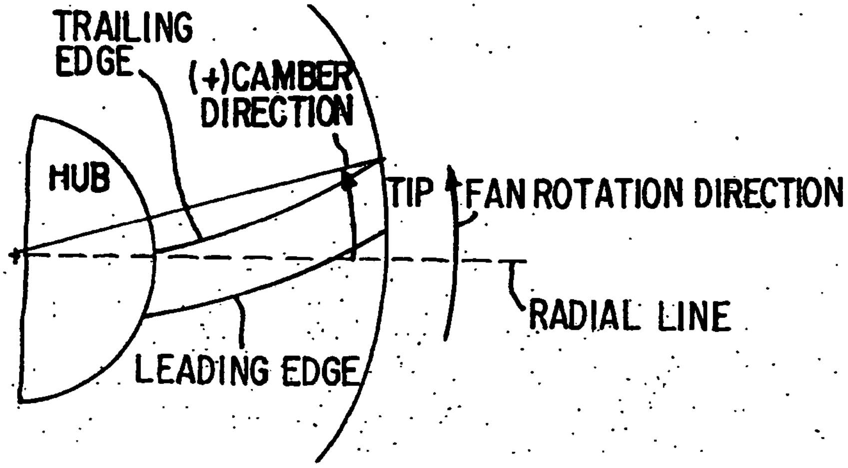

TRAILING EDGE
(+)CAMBER DIRECTION
HUB
TIP
FAN ROTATION DIRECTION
RADIAL LINE
LEADING EDGE

FIG-23

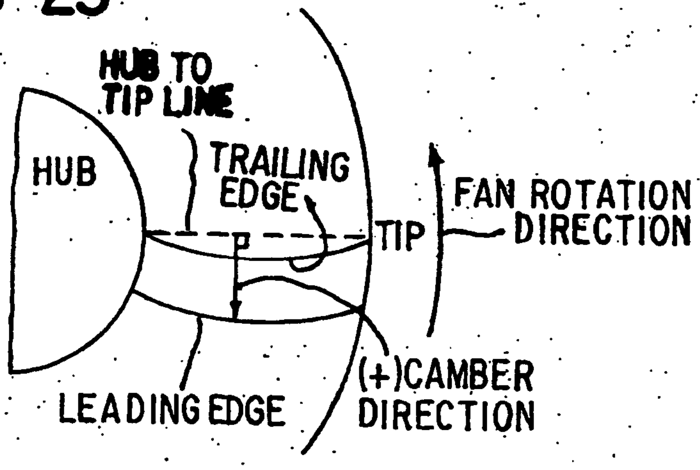

HUB TO TIP LINE
HUB
TRAILING EDGE
TIP
FAN ROTATION DIRECTION
LEADING EDGE
(+)CAMBER DIRECTION

FIG-24A

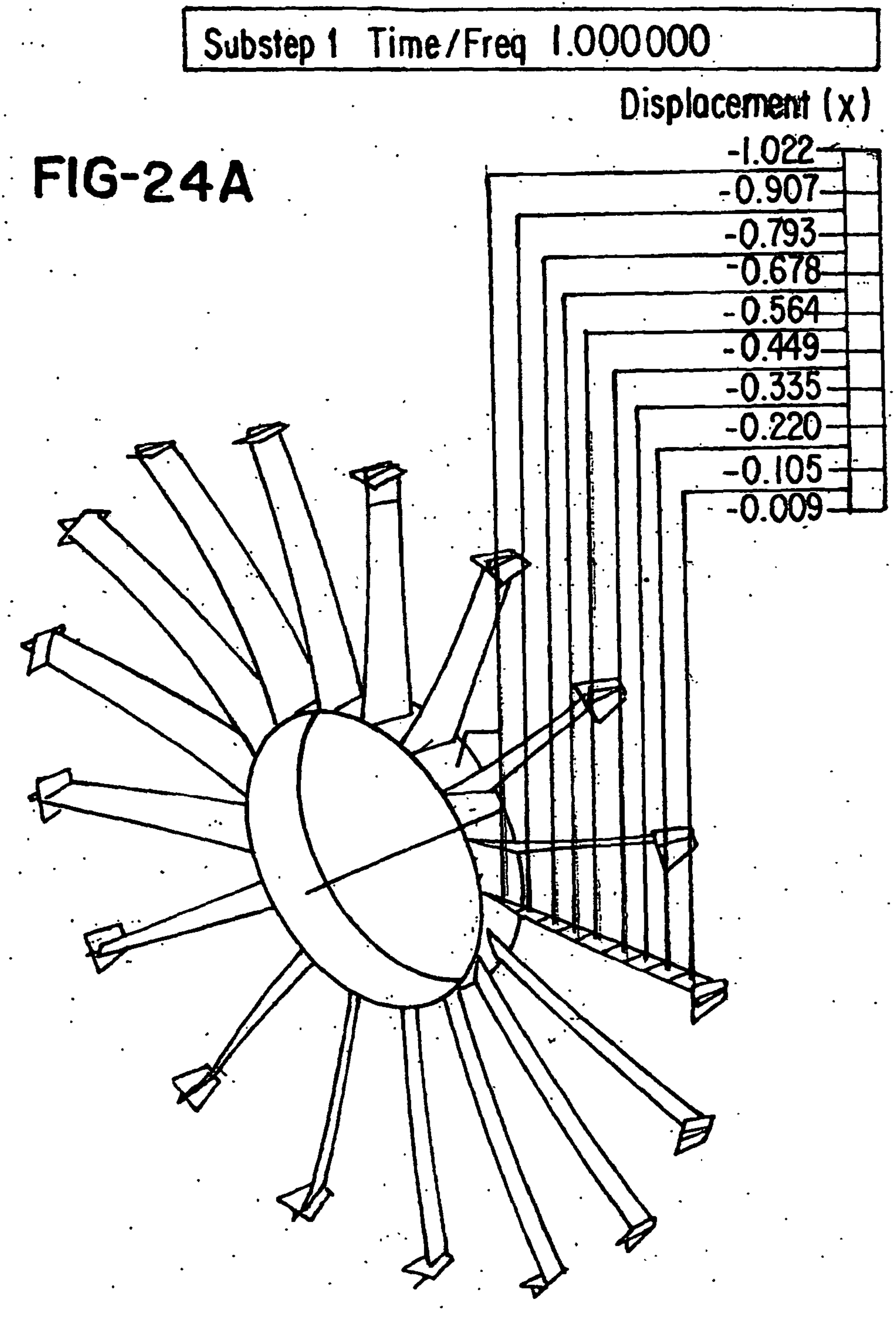

Substep 1 Time/Freq 1.000000
Displacement (x)
-1.022
-0.907
-0.793
-0.678
-0.564
-0.449
-0.335
-0.220
-0.105
-0.009

FIG-24B

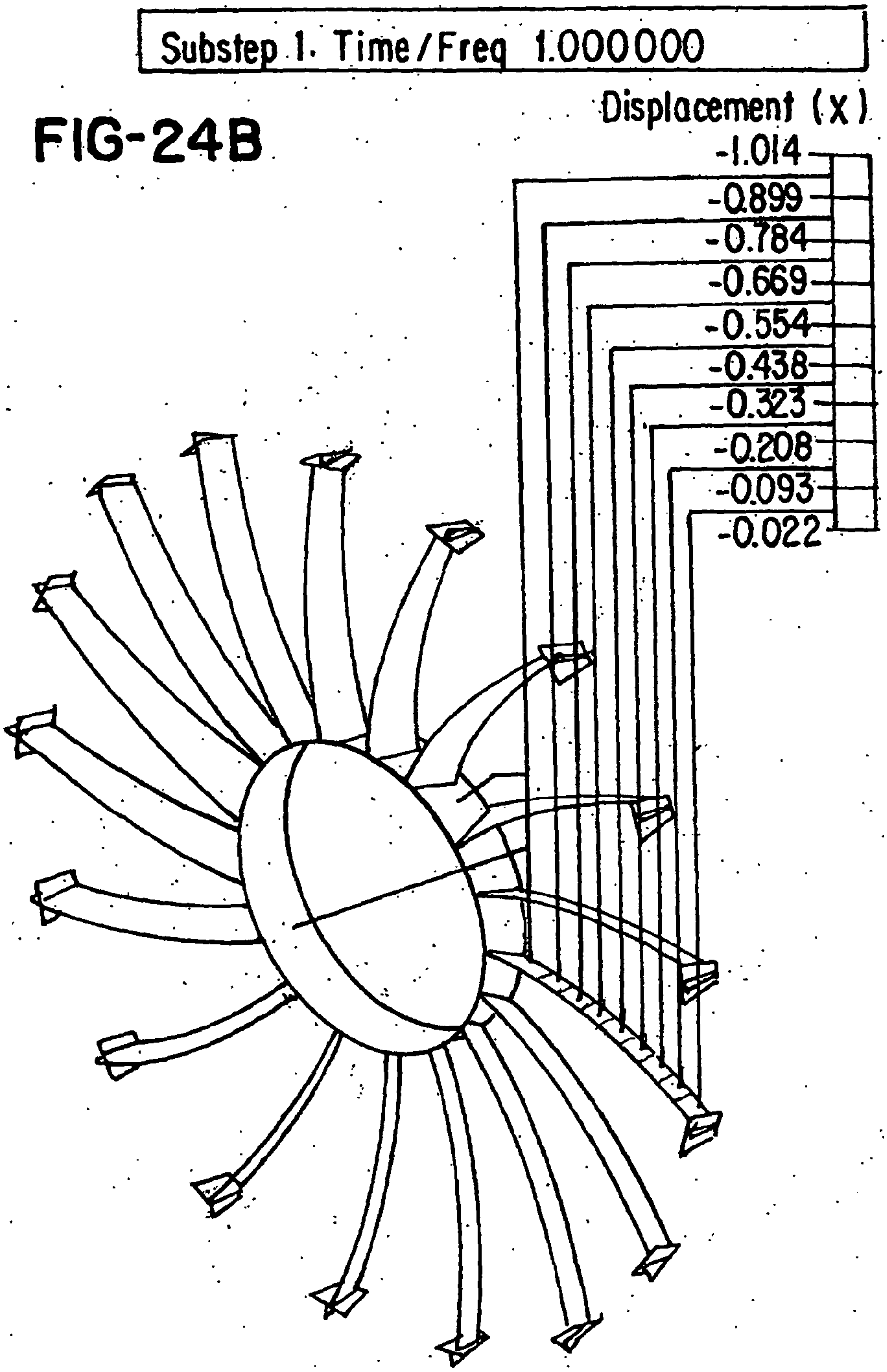

Substep 1. Time/Freq 1.000000
Displacement (x)
-1.014
-0.899
-0.784
-0.669
-0.554
-0.438
-0.323
-0.208
-0.093
-0.022

FIG-25A

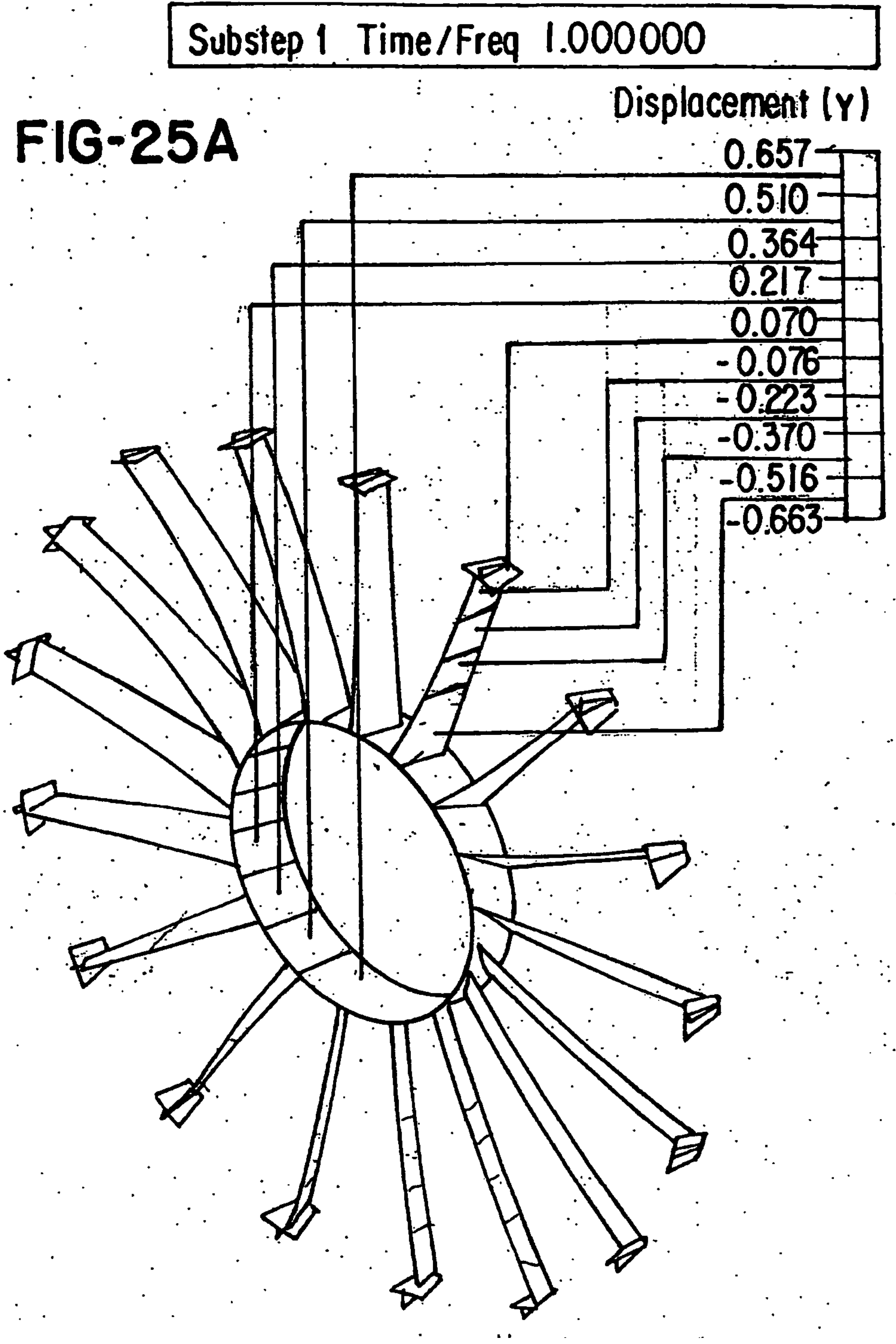

Substep 1 Time/Freq 1.000000
Displacement (Y)
0.657
0.510
0.364
0.217
0.070
-0.076
-0.223
-0.370
-0.516
-0.663

FIG-25B

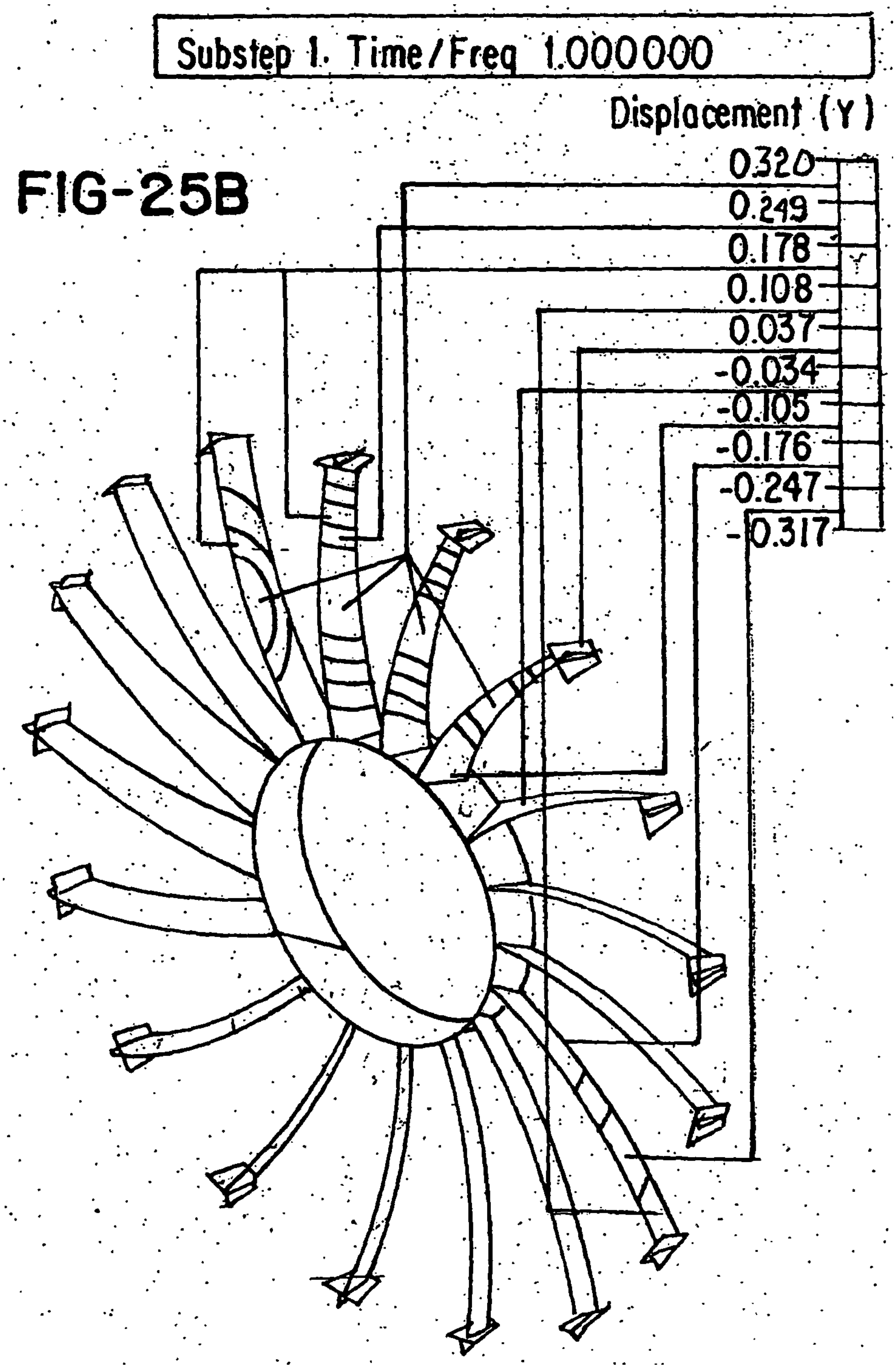

Substep 1. Time/Freq 1.000000
Displacement (Y)
0.320
0.249
0.178
0.108
0.037
-0.034
-0.105
-0.176
-0.247
-0.317

FIG-26A

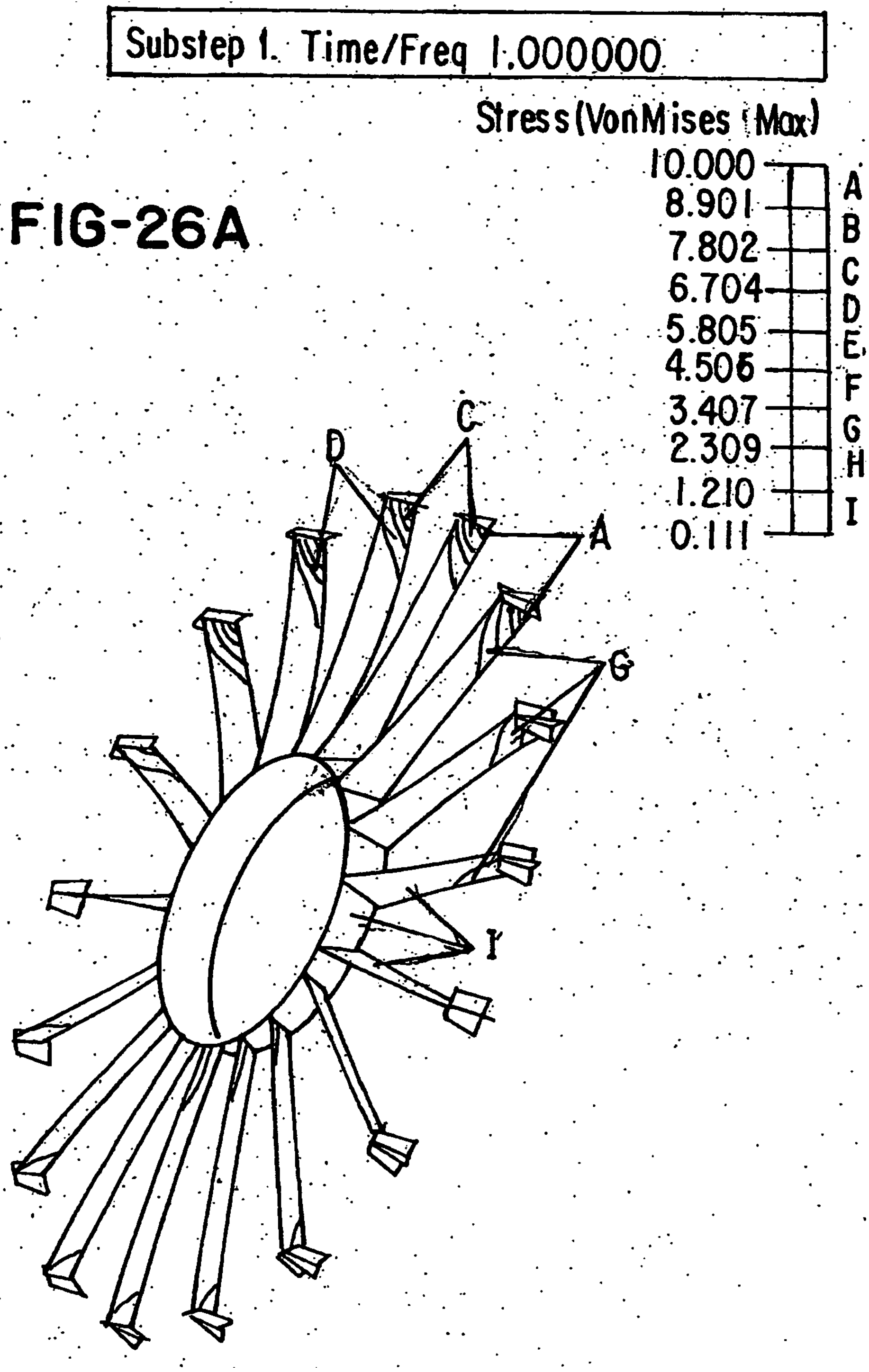

Substep 1. Time/Freq 1.000000
Stress (VonMises Max)
10.000
8.901
7.802
6.704
5.805
4.506
3.407
2.309
1.210
0.111
A
B
C
D
E
F
G
H
I
C
D
A
G
I

FIG-26B

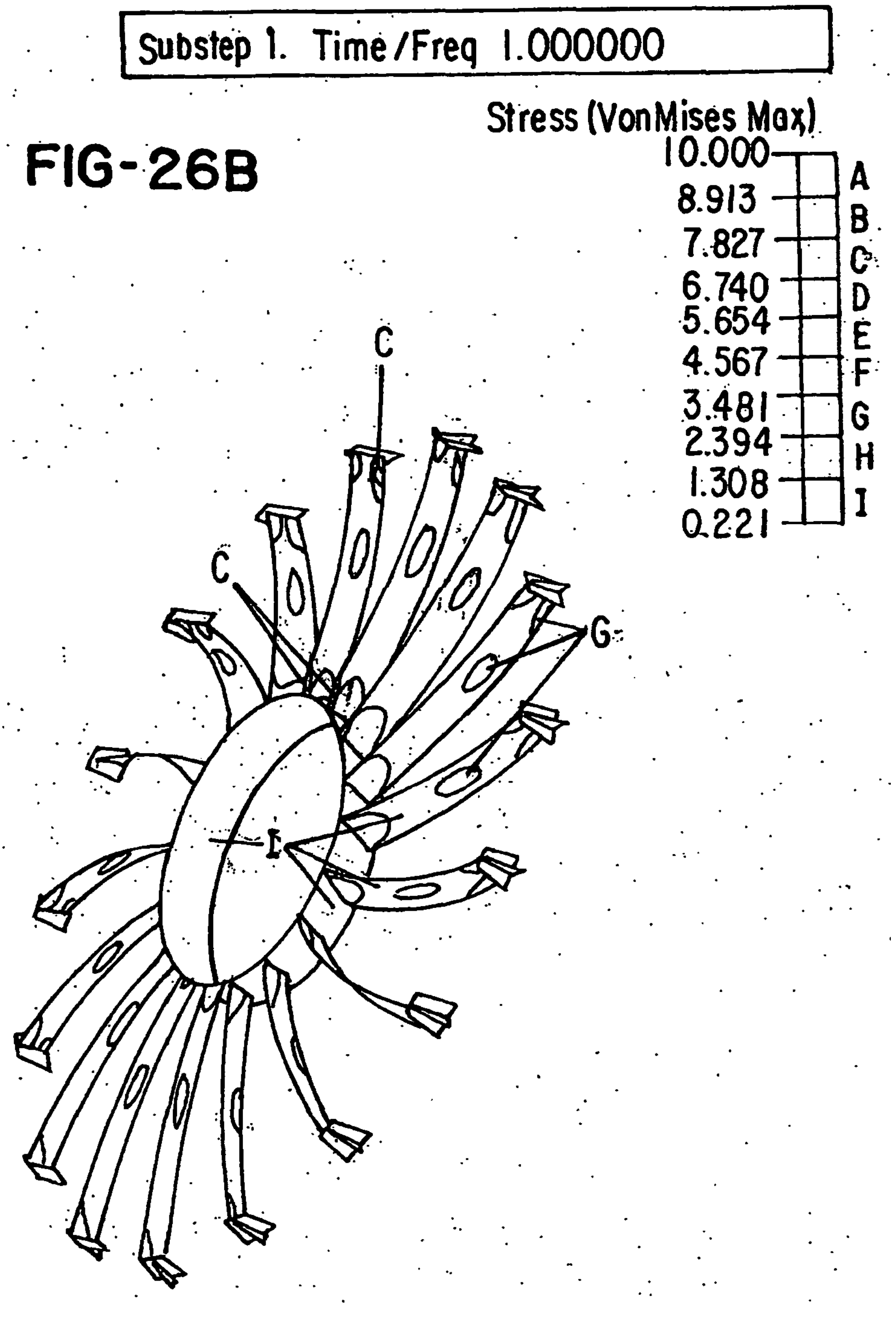

Substep 1. Time/Freq 1.000000
Stress (VonMises Max)
10.000
8.913
7.827
6.740
5.654
4.567
3.481
2.394
1.308
0.221
A
B
C
D
E
F
G
H
I
C
C
G
I

FIG-27A

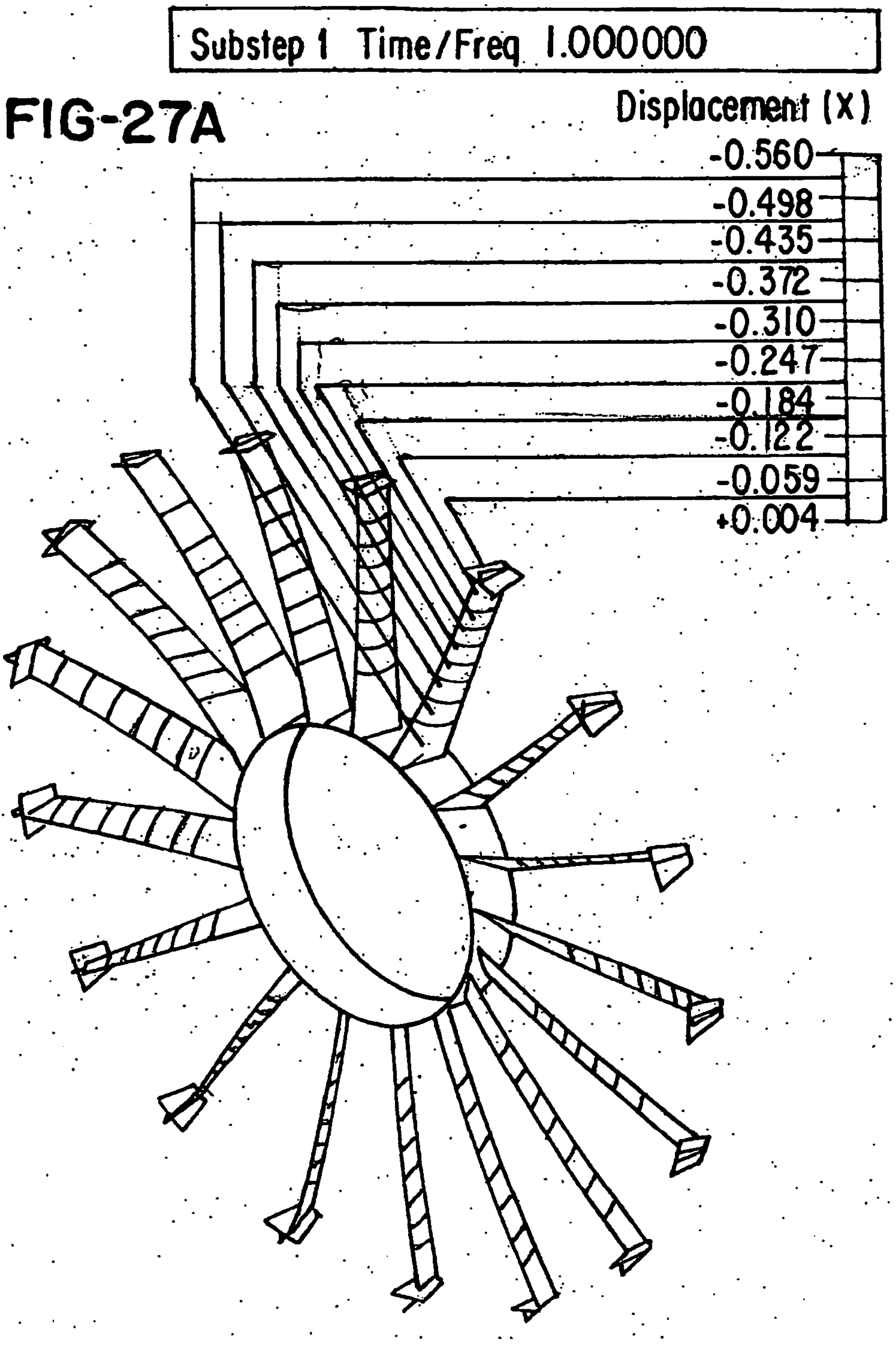

Substep 1 Time/Freq 1.000000
Displacement (X)
-0.560
-0.498
-0.435
-0.372
-0.310
-0.247
-0.184
-0.122
-0.059
+0.004

FIG-27B

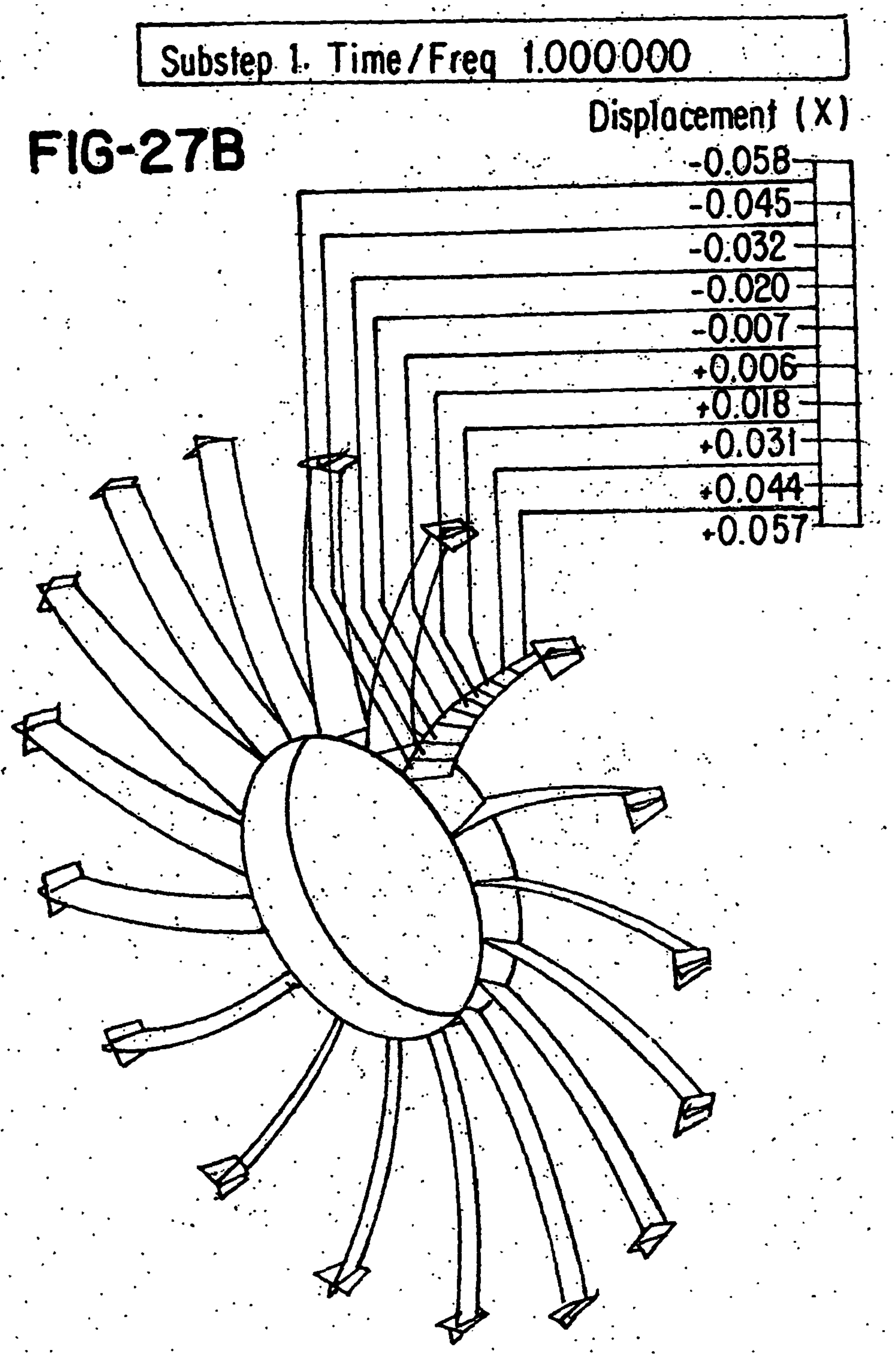

Substep 1. Time/Freq 1.000000
Displacement (X)
-0.058
-0.045
-0.032
-0.020
-0.007
+0.006
+0.018
+0.031
+0.044
+0.057

FIG-28A

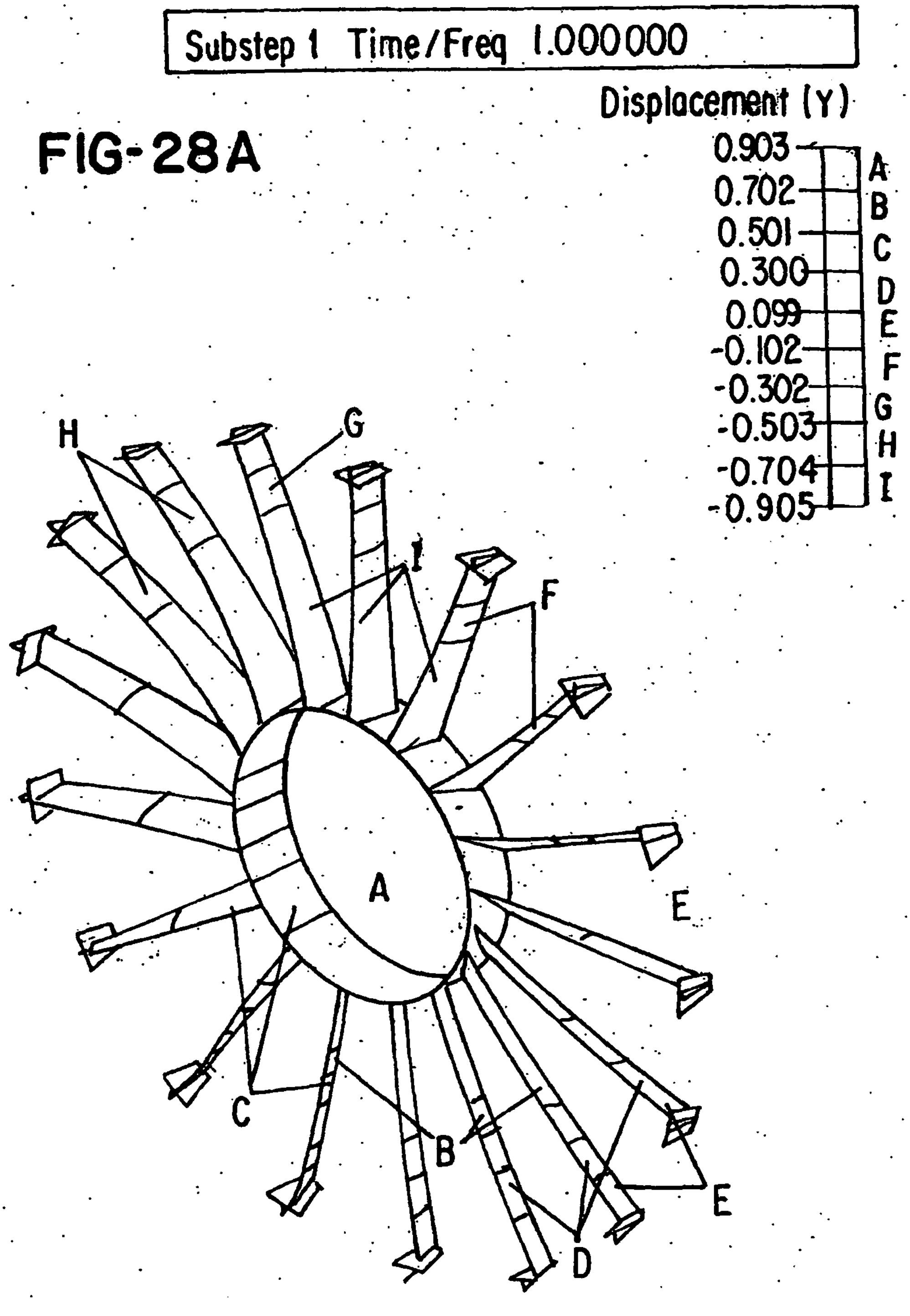

Substep 1 Time/Freq 1.000000
Displacement (Y)
0.903
0.702
0.501
0.300
0.099
-0.102
-0.302
-0.503
-0.704
-0.905
A
B
C
D
E
F
G
H
I
H
G
I
F
A
E
C
B
E
D

FIG-28B

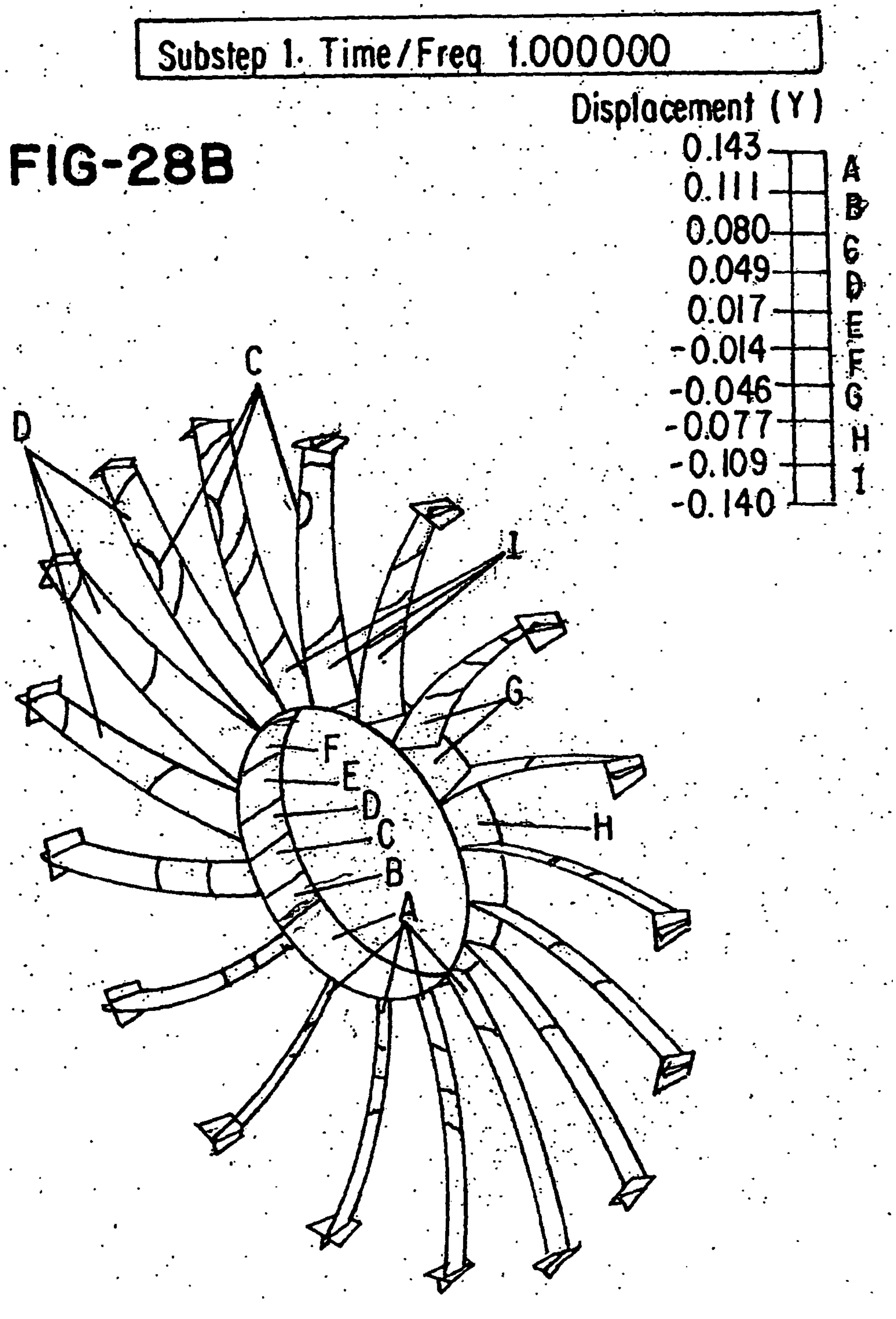

Substep 1. Time/Freq 1.000000
Displacement (Y)
0.143
0.111
0.080
0.049
0.017
-0.014
-0.046
-0.077
-0.109
-0.140
A
B
C
D
E
F
G
H
I
C
D
I
G
F
E
D
C
B
A
H

FIG-29A

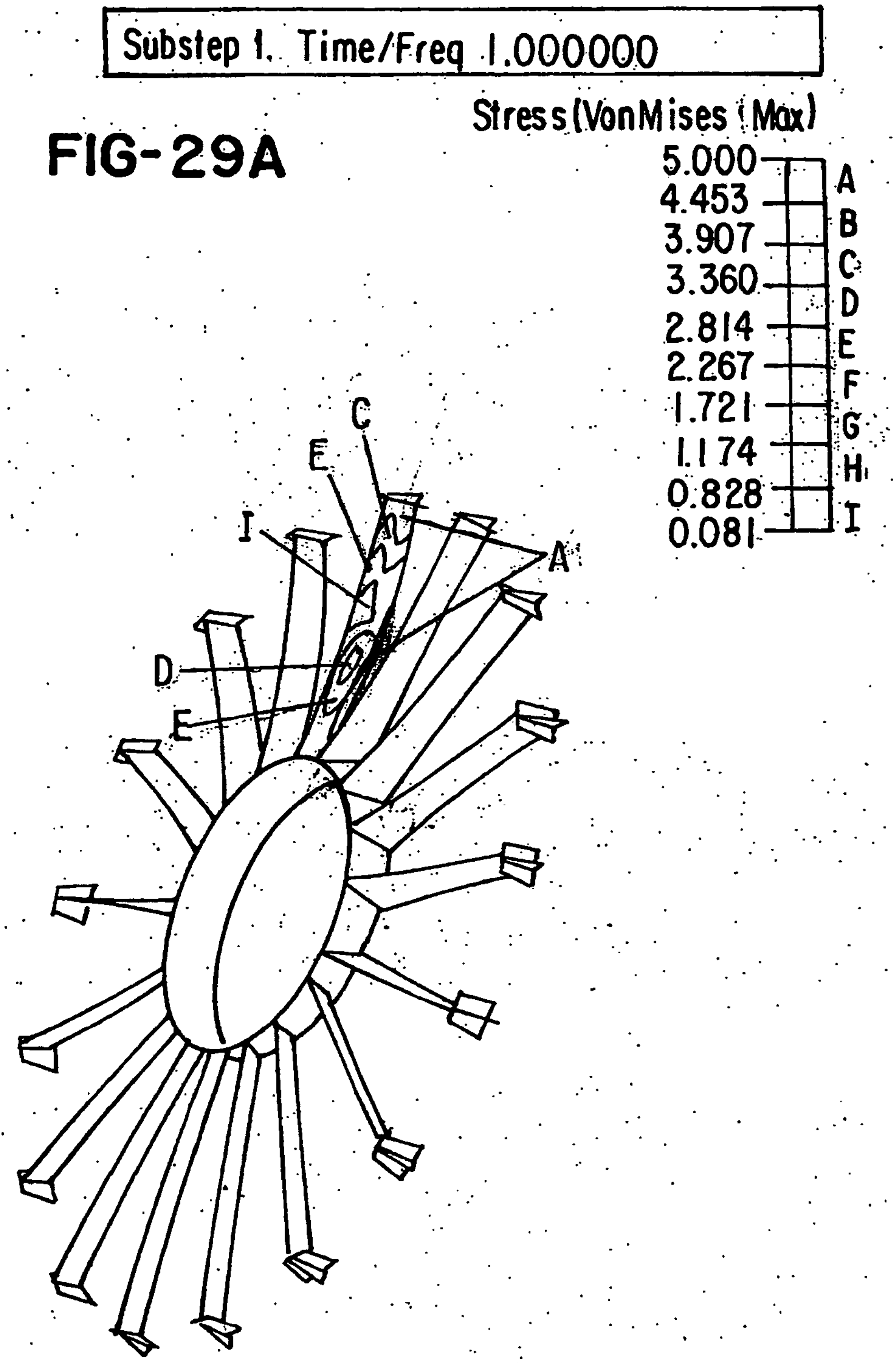
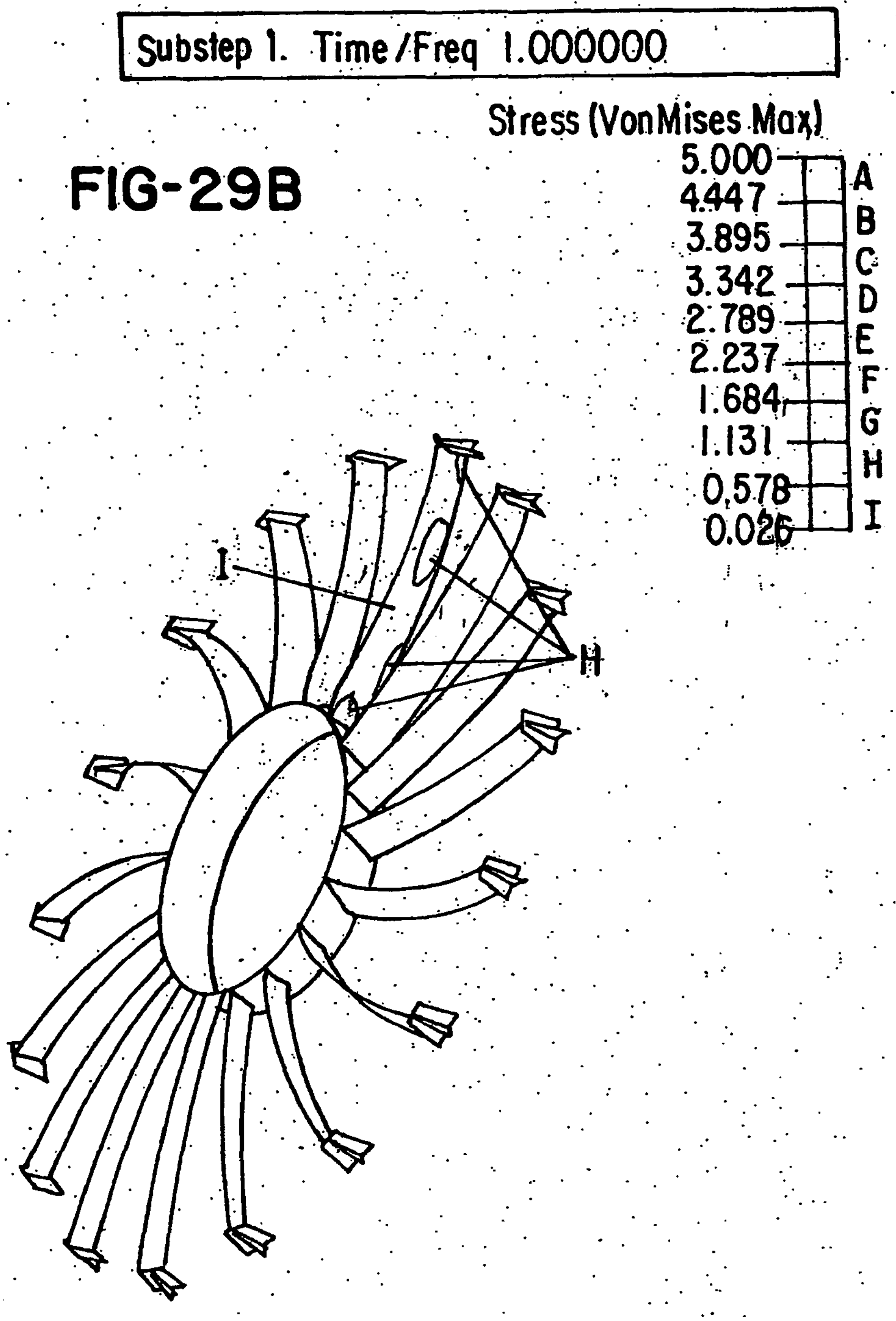

Substep 1. Time/Freq 1.000000
Stress (VonMises (Max)
5.000
4.453
3.907
3.360
2.814
2.267
1.721
1.174
0.828
0.081
A
B
C
D
E
F
G
H
I
C
E
I
A
D
E

FIG-29B


Substep 1. Time/Freq 1.000000
Stress (VonMises Max)
5.000
4.447
3.895
3.342
2.789
2.237
1.684
1.131
0.578
0.026
A
B
C
D
E
F
G
H
I
I
H

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 6139265 A **[0002] [0006]**
- US 5342167 A **[0006]**
- US 2154313 A **[0006]**
- FR 1499693 A **[0006]**
- EP 1312754 A **[0006]**
- DE 4228879 A1 **[0006]**